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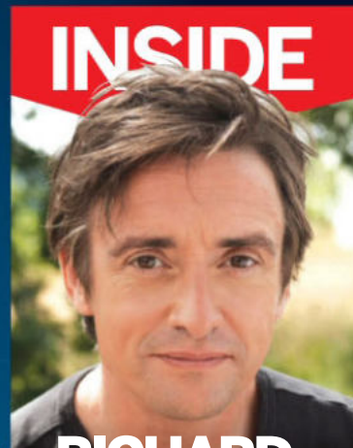
THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

INSIDE



RICHARD HAMMOND
TV's petrolhead talks science and car tech

APPLE WATCH

Sensors detect your heart rate

Pay for your shopping and unlock your hotel room

See the revolutionary tech inside

Accelerometer tracks movement

+10 AMAZING NEXT-GEN WEARABLE GADGETS

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25 facts about the force that holds galaxies together

MISSION TO MARS

How humans will one day conquer the Red Planet

CALORIES
Find out how the energy in your food is calculated

LIFE IN THE CORAL REEF
Discover what lives in the rainforest of the seas

AIR TRAFFIC CONTROL
A behind-the-scenes look at how the skies are kept safe

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ISSUE 71

WELCOME

The magazine that feeds minds!

Page 54
What creatures call the coral reef home?

Free tickets to Gadget Show Live 2015

the Gadget Show LIVE

We have partnered up with the Gadget Show Live 2015 and are delighted to offer all subscribers two free entry tickets to the show. An email will be sent out on 20 March for you to claim your free tickets. Please ensure you have provided us with a valid email address, you can add your email address via 'my account' on **www.imaginesubs.co.uk** or by calling our customer team on UK 0844 815 5944 or overseas +44(0) 1795 418 680.

Ever wondered what the Red Planet smells like? Pennies and loneliness. That's according to Nasa's Mars Rover Curiosity. The parody Twitter account @SarcasticRover is pretty peeved after travelling 483 million kilometres (300 million miles), and is not impressed by the new surroundings: "Got a rock in my tread… fantastic. I already hate this place. John Carter can have it." (For official updates, check out @MarsCuriosity.)

Whatever hardships the sassy rover might be going through, however, is nothing compared to the people working to make Mars our second home in the stars. Among the more unusual experiments is trying to making urine a resource of water and even electricity. Pee is for power, people. Find out what other preparations are underway on page 64.

Also dominating the headlines is the long-awaited Apple Watch, which leads our wearable tech feature on page 16. With this release, and their second office campus only a year off completion, things are going well for Apple. Hopefully they won't have any trouble installing windows…

Jodie

Jodie Tyley
Editor

Meet the team…

Andy
Art Editor
Designing the feature on life in the coral reefs made me want to get on a plane, pull on some flippers and go snorkelling.

Erlingur
Production Editor
It's mad to think humans will catch, research and possibly mine asteroids in my lifetime. That would change the plot of *Deep Impact* somewhat….

Phil
Staff Writer
The driverless Audi RS7 can navigate a racetrack with accuracy that I could only dream of. Its parallel park is probably better, too.

Jackie
Research Editor
By 2050, we may have the answer David Bowie's 44-year-old question, "is there life on Mars?" Discover the mission plans this issue!

Jo
Assistant Designer
After watching the *Theory Of Everything* at the cinema I enjoyed learning more about Stephen Hawking's wheelchair this month.

Jo
Senior Staff Writer
I got to visit a real-life air traffic control centre this month, but you don't need to worry, I didn't touch any buttons.

What's in store

Check out just a small selection of the questions answered in this issue of How It Works…

Why do we crave sweet things? **Page 38**

How was Devil's Tower formed? **Page 58**

How can this helmet warn of collisions? **Page 50**

How do planetariums recreate space? **Page 26**

Why have some planets gone rogue? **Page 71**

How was wine made in Ancient Israel? **Page 77**

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Plus ten amazing next-gen wearable gadgets and the technology behind them

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30 25 facts about gravity

Meet the experts...

Laura Mears
Gravity
Think you know all about the force that keeps your feet on the ground? Think again. You'll be amazed by Laura's list of 25 facts. Did you know gravity is lumpy, or that our weight changes as we accelerate? Nope, us neither.

Hayley Paterek
Dragonflies
Did you know dragonflies existed before the dinos? If you know Hayley, you'll certainly be aware. It's her favourite fact from this month's assignment and she's telling everyone.

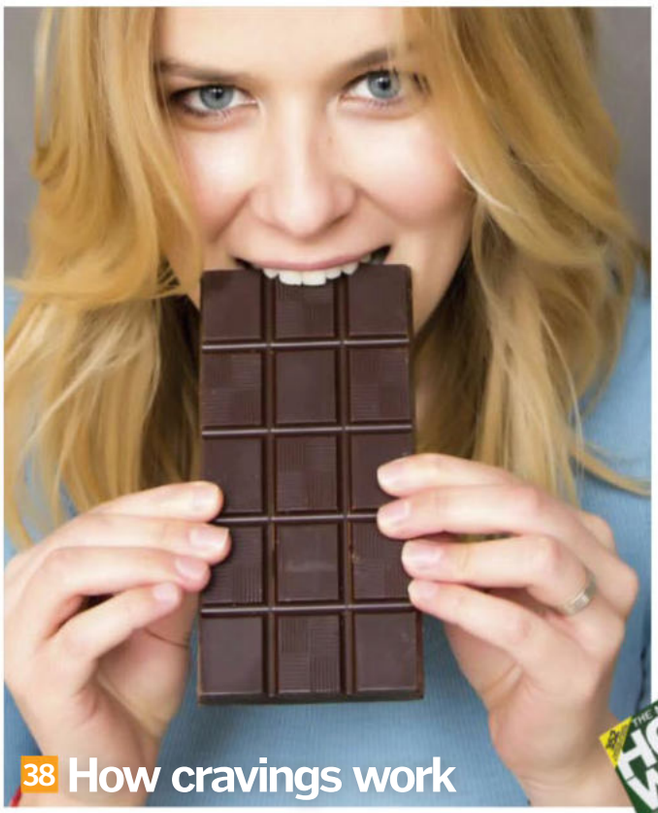
James Hoare
Easter Island
The Editor in Chief of **History Of War** and **All About History** unravels the mysteries of two lost civilisations this month: the Anasazi peoples of North America and the intriguing inhabitants of Easter Island.

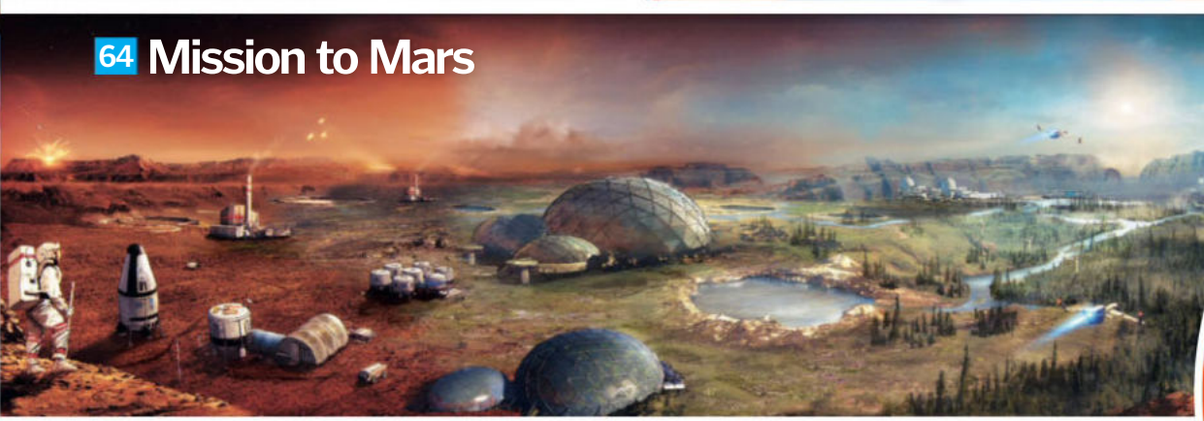
Jack Griffiths
Smallest manned aircraft
Before Jack relocated, he had a gruelling 40-minute commute on the train. He very much wished he had owned a one-man aircraft like the one on page 51.

Ceri Perkins
Apple Watch
Who better to write about Apple's biggest release than our Big Apple-based writer Ceri? She breaks down the tech behind the trendiest wearables, revealing not just what they do, but how they do it.

How do we know that dogs can tell if someone is lying to them? Find out on pg 13

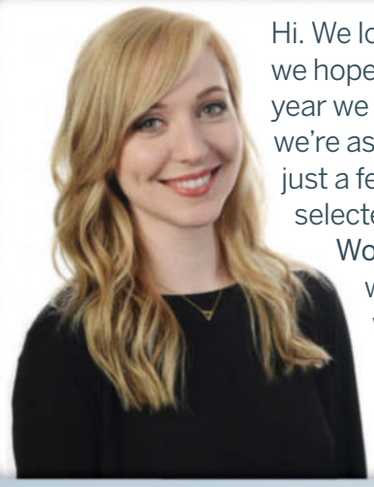
REGULARS





Join our HOW IT WORKS Reader Panel today!

Take our three-minute survey at howitworksdaily.com/survey and win a place on our panel

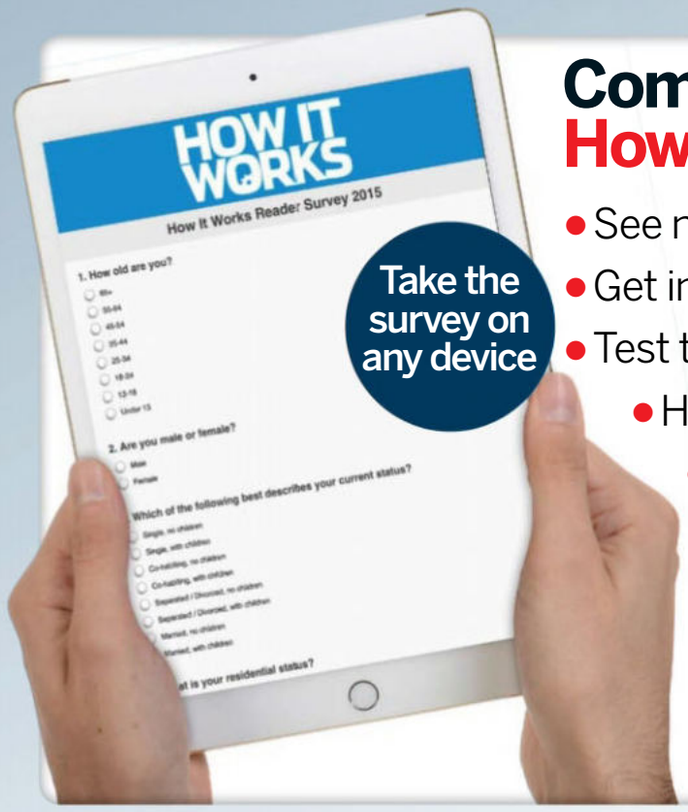


Hi. We love making How It Works and we hope you love reading it too. But this year we want to make it even better, so we're asking for your help. By answering just a few questions, you could be selected to join our first-ever How It Works panel. I'm so excited to hear what you have to say and can't wait to learn more about you.

Jodie

Jodie Tyley
Editor

Join our panel and help us make the magazine even better!



Complete our survey to join our How It Works panel and:

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- Test third-party products for review
- Have a chance to meet the How It Works team
- Shape the future issues of the magazine
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Take the chance to get closer to the team than ever before

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Complete our survey and win your place today

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The science behind the blue ice caves

Explore the incredible insides of the Vatnajökull glacier

Deep inside Iceland's largest glacier, you'll find a network of breath-taking caves. These natural ice caves form when the surface of the glacier melts in summer. The resulting water then falls through holes, known as moulins, in the surface and cuts through the ice to form enormous cavities.

Eventually, the rivers of water exit at the glacier's tongue, creating the opening to the cave. Warm air flowing through the caves also helps shape the ice, often creating wave-like patterns along the walls.

This process takes place every year, creating slightly different cave formations each time. Then, in winter, the melting stops and the rivers run dry, enabling tourists to enter and explore this wondrous environment for themselves.

Why are the caves so blue?

The stunning blue colour of the caves is a result of the light waves that travel through the ice. Without bubbles of air trapped inside to scatter the light, the thick, compacted ice absorbs wavelengths at the red end of the colour spectrum, so that only the blue wavelengths are reflected. The thicker the ice, the bluer it appears as the light waves have further to travel and so more red wavelengths are absorbed along the way. However, when the Sun is low in the sky or if a fire is lit inside the cave, golden orange light can reflect off of the parts of the cave walls to create a colourful display.

Temperatures inside the caves are warmer than outside, ranging from -12 to 5°C (10 to 41°F)

Photographer Einar Runar Sigurdsson runs guided tours of the Vatnajökull glacier caves

Space balloon aces first flight

You could soon visit the edge of space in a giant balloon

The possibility of tourist trips to the edge of space has taken a giant leap closer, after World View conducted a successful test flight of its space balloon. The helium-filled balloon steered by an aerodynamic parachute called a parafoil reached 31,150 metres (102,200 feet), higher than any parafoil has ventured before. The company hopes that it will be able to send paying customers up with it in an attached pressurised capsule in 2016. We suggest you start saving up now though, as one trip is expected to set you back about £50,000 ($75,000).

The balloon expands to ascend, then helium is vented to begin the descent

The luxury capsule can seat six and has a large viewing window, bar, toilet and internet access

AMAZING VIDEO!

See the amazing view from the space balloon's test flight

www.howitworksdaily.com

World's strongest natural material discovered

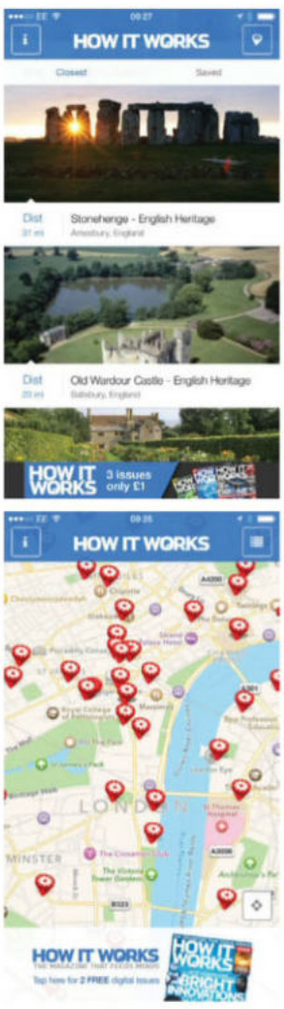
Limpet teeth set new strength record

Limpets use their teeth to scrape algae off of rocks, but quite often take some of the rock with it too

For years, spider silk has been considered the strongest biological material, but it has now been knocked off the top spot by a tiny mollusc. Scientists have discovered that a limpet's teeth can withstand the same amount of pressure needed to turn carbon into diamond. The teeth are made up of tiny fibres that contain an iron-based mineral called goethite. The way these mineral fibres are tightly packed together creates an incredibly strong structure that it's hoped can be mimicked to engineer tougher man-made materials for use in cars, aircraft and boats in the future.

A limpet's teeth are less than a millimetre long, but would be the same strength no matter what their size

Save venues to your list of favourites or share them with friends and family



Discover Great Days Out for all the family

Find fascinating new places to visit with our free app

There are thousands of fun and educational places to visit in the UK, and we want to help you find them. That's why we've created our new **How It Works: Great Days Out** app. Download it from the App Store onto your iOS device and browse the map to find nearby places of interest, including museums, galleries, national parks and zoos. You can also find helpful visitor information, such as opening times and entry prices, plus get directions to help you find your way there quickly and easily. Don't forget to let us know about the amazing places you visit by posting your comments and photos on our Facebook and Twitter pages!

GLOBAL EYE

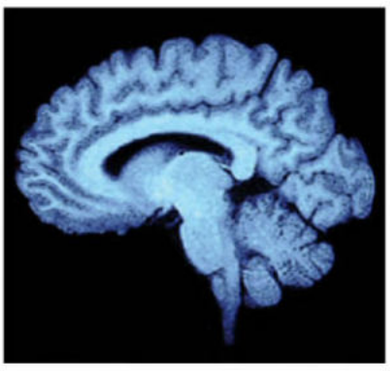
10 COOL THINGS WE LEARNED THIS MONTH

You can turn your body into a touchscreen

Keep breaking or misplacing your phone? The Cicret may be the answer. Promising to include all the functions of a smartphone and tablet, this small bracelet will project a touchscreen straight onto your wrist. Motion sensors allow you to control the projection just like a screen of a smartphone and the £300 ($460) gadget will support Wi-Fi straight out of the box.

Mind gyms could be the future

Need a stress-free lunch break? Clear your head in the new 'mind gym' – called Orrb – that allows office workers to relax. Each pod contains a selection of wellness routines that lets you escape the workplace and unwind to meditation programmes. A sanctuary away from the stress of daily life, the Orrb is also being trialled in universities and airports.

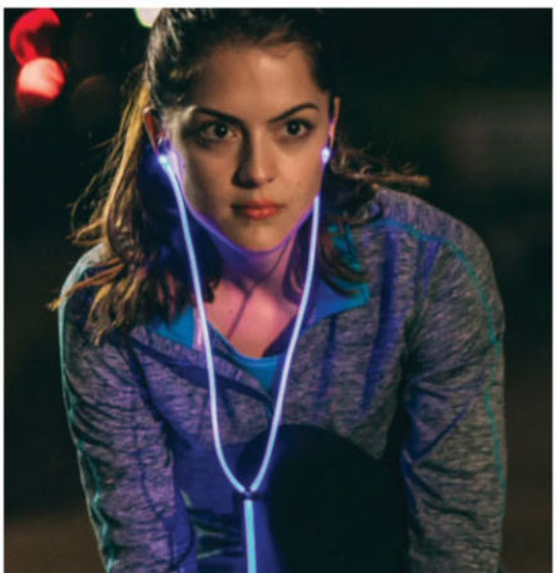


Alzheimer's could be delayed

Scientists have discovered a molecule that could delay the onset of Alzheimer's disease. It works by reducing the amount of sticky clusters of protein in the brain, which have been linked to memory loss and other symptoms. The molecule occurs naturally in the human body and could have a massive medical impact if scientists find a way of administering it as a drug.

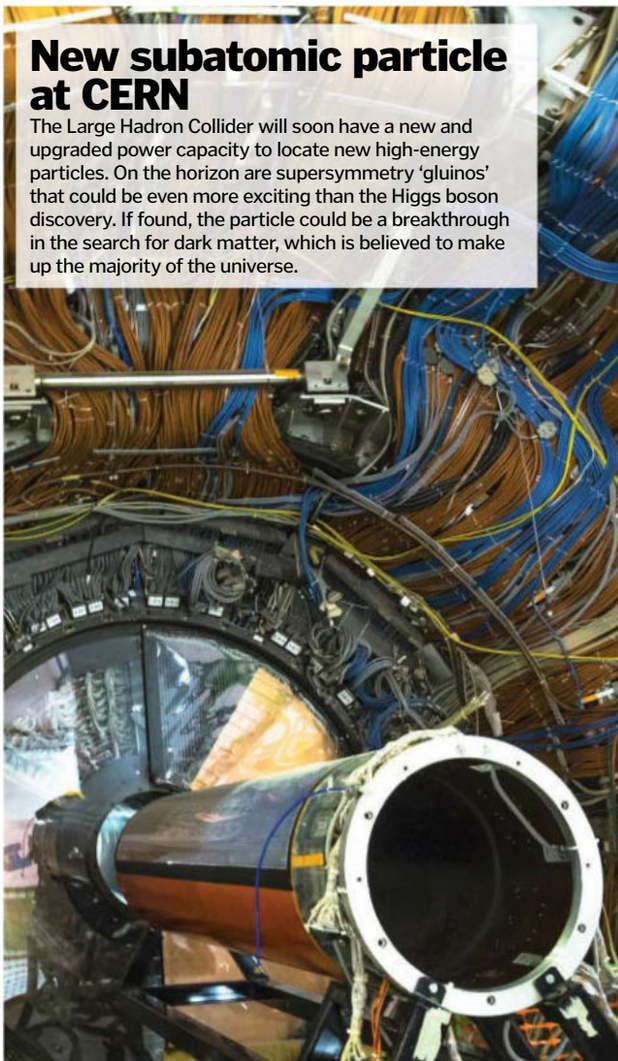
There are glow-in-the-dark headphones

These headphones illuminate to the rhythm of your music. They work by using specially designed wires that diffuse light from a laser in red, green or blue. Known as Glow, the cool contraption will set you back about £100 ($150) but it's not just about pretty colours. The headphones will also enable you to answer calls, stream apps and even control Instagram.



New subatomic particle at CERN

The Large Hadron Collider will soon have a new and upgraded power capacity to locate new high-energy particles. On the horizon are supersymmetry 'gluinos' that could be even more exciting than the Higgs boson discovery. If found, the particle could be a breakthrough in the search for dark matter, which is believed to make up the majority of the universe.



Dogs can tell if you're lying

Man's best friend can sense whether you're trustworthy, according to a new study. The dogs were directed to a container with food hidden inside, which they ran toward. In the second test, they were directed to an empty container, and in the third test, most of the dogs ignored the instruction.

There's a cream to remove tattoos

The only way to get rid of unwanted body art used to be a painful laser, but not any more. A cream known as Rejuvi has come to the UK from the USA that injects into the skin and bonds with the ink. The unwanted pigment is then pushed to the surface and removed with much less pain than the original procedure.

New tech reveals the true face of Anne Boleyn

CCTV technology has revealed a painting initially thought to be Henry VIII's third wife, Jane Seymour, as actually a portrait of Anne Boleyn. Facial-recognition software developed at the University of California was used to compare the measurements and unique features from the only undisputed contemporary image of Anne – on a commemorative medal from 1534 – to confirm the match.

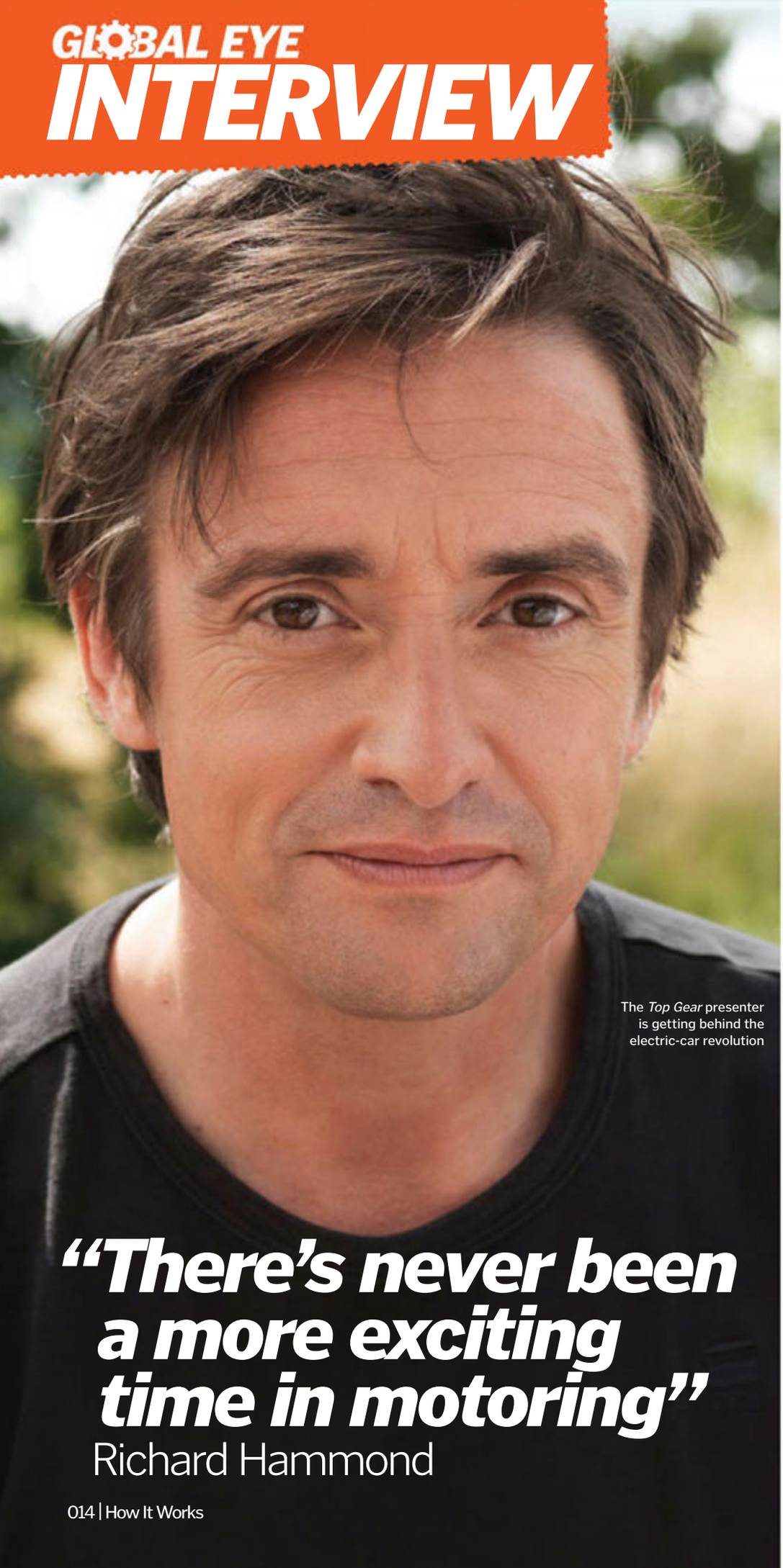
Milky Way under threat

A hydrogen cloud known as Smith's Cloud is set to collide with our galaxy in the future. As massive as a million Suns, it will bring extragalactic material to our Solar System. Don't worry though, it's not due to strike until about 27 million years from now.

The age of sail returns

Looking incredibly futuristic, the Vindskip cargo ship could be the next generation of ship propulsion. Using its large hull like a sail, strong sea winds power and manoeuvre the vessel. When the wind isn't blowing, environmentally friendly liquefied natural gas (LNG) takes over so the ship will never be stranded in still weather. Reducing carbon dioxide emissions by 80 per cent, this could well be the future of sailing.

INTERVIEW



The *Top Gear* presenter is getting behind the electric-car revolution

"There's never been a more exciting time in motoring"

Richard Hammond

Explaining stupidity with science and discussing the latest car tech with Top Gear's resident boffin

From Ice Bucket Challenges that went wrong to daring bike stunts that end in disaster, the internet is full of hilarious stunt videos we can't tear our eyes away from. Now *Top Gear* presenter Richard Hammond is making it his mission to explain the scientific principles behind these unfortunate mishaps, showing exactly why you shouldn't try them at home.

Although most people will be used to seeing Hammond on their TV screens talking about the latest cars on BBC's *Top Gear*, he also knows quite a bit about science too. Having presented the explosion-heavy show *Brainiac: Science Abuse,* as well as countless other fascinating documentaries, Hammond can now be found on National Geographic's *Science Of Stupid*, using stunning slow-motion video to uncover exactly where YouTube's amateur stuntmen and women got it wrong. We caught up with him to discuss his love of science, as well as find out his opinion on the latest car tech, of course...

How would you sum up your show *Science Of Stupid*?

It's providing two things. It's showing hilarious clips of people doing stupid things that are often painful, but what's even better is that it's giving us an excuse to enjoy them because it's in the pursuit of scientific knowledge and understanding. We're having the things they've done explained, so we're learning why they've fallen over, or fallen off or landed flat on their face, and I hope it's an easily digestible form of science.

What's your favourite thing about watching all those crazy stunt videos?

I always love the ambition that you can see in people's eyes, when in their mind they can see it unfold in one way but then it doesn't go to plan. We've had clips of people jumping into a swimming pool that turned out to be frozen or spinning around on office chairs and it's just gone horribly wrong. I just like that moment when you can see how they imagine it's going to go and after you've seen the science explained you then know it's not going to work and you want to shout at them: "Stop, it's going to hurt!"

3 lessons from Science Of Stupid...

1 Head spinning
Breakdancers attempting to spin on their heads need to keep their legs low to ensure that their centre of gravity is directly over their head for balance.

2 Cycling on walls
A curved wall will help to create centripetal force, where inertia pushes the bike against the wall, increasing the friction created by the tires.

3 The standing jump
To jump from a static position onto a raised platform, you need to squat first to create more kinetic energy as you push against the ground.

Science Of Stupid uses slow-motion video and diagrams to explain the laws of science

"I've always loved cars, motorcycles and bicycles and I love knowing how they work"

What is the most stupid thing you have ever attempted that you can now explain with simple science?
I've done a number of things. I remember when I was a kid I was forever building ramps for my bicycle to try and jump like Action Man. Generally, my problem would be one of trajectory, speed and momentum and quite often the rigidity of the materials I was using for the ramp, as they weren't able to support my bicycle. So that failed on a number of levels. Also, our garage wall was next to the house next door and I used to try and climb up between the two walls using friction, which was great but I would then tire halfway and gravity would take hold and do all the remaining work for me.

Have you always had an interest in science?
I have always loved cars, motorcycles and bicycles, and I love knowing how they work. When I was a kid I used to build bicycles all the time. I had boxes and boxes of old bicycle parts and I'd assemble them, so I was fascinated in mechanics, which lead very nicely to physics and science in general.

So I've always had an interest in it, but I'm not by any means any kind of scientist. I enjoy making shows with that approach, though. I'm not standing there telling the audience what I know; I'm often finding out along with them. I think there is a place for proper grown-up, in-depth science programmes [on television], but that doesn't mean there is less of a place for shows like this too. You don't need to be a scientist; it's just great stuff to talk about down the pub.

What's the most fascinating science fact you've learnt while presenting the show?
Loads! There's the conservation of angular momentum, when people draw their legs in if they're spinning to do a back-flip or whatever. If you halve your body length you actually multiply your rotational speed by four. And it's great because you can see that actually working with slow-motion footage on the show.

As a motor enthusiast, what car-related technology are you most excited about at the moment?
Obviously fuel and power sources are critical. Alternative sources are great, whether or not that is ultimately going to mean electric cars, who knows, because there's the issue of where the electricity comes from. It's a fascinating area and [on *Top Gear*] we are often asked: "What are you going to do when it all goes electric?" Well, we'll have more to talk about!

There's never been a more exciting time in motoring. There's fuel efficiency in petrol cars as well. Everything's going to be fitted with small turbos and small-capacity engines to increase fuel efficiency. And the on-board technology in terms of connectivity with your smartphone and what that will enable your car to do. I was thinking the other day how crazy it is that you can update the software in your phone, computer, tablet etc, whereas your car just is what it is. So they should be updateable and I don't doubt that they will be very soon.

Do you think driverless cars are a good idea?
As an enthusiastic driver, that is never going to appeal to me too much. I have to travel a lot and there are journeys I suppose, such as when I'm sitting on the M4 again, when I think vehicles that can electronically hook up and form a giant train that you can join or leave at will, there's sense to that. But personally I have cars and motorcycles going back to the 1920s so I really enjoy operating the old stuff as well, which is very much not driverless, it's driverful.

If you could invent a new gadget that would make driving even more enjoyable, what would it be?
If it's going to be more enjoyable, it would involve finessing things such as making electric steering have more feel, which is coming. I think its about refining what we'll need for cars to work in terms of efficiency, which is why they've put electric steering in, but putting the feel back in and making sure it still feels engaging and viscerally exciting to drive.

APPLE WATCH

+10 AMAZING NEXT-GEN WEARABLE GADGETS

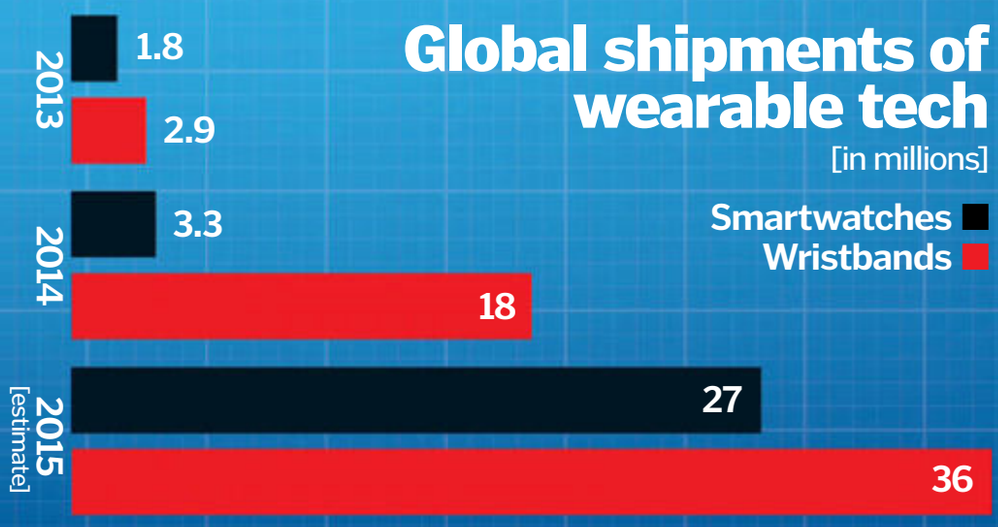
What did the first wearable computer look like?

A An abacus on a ring B A digital wristwatch C A brilliant Hallowe'en costume

Answer:
In the 17th century, the Chinese Qing dynasty created a tiny (1cm by 0.5cm / 0.4in by 0.2in) but fully functioning silver abacus on a ring. The computer could be used to count and make calculations while it was being worn.

DID YOU KNOW? *Wearable tech was the most tweeted-about topic at CES 2014, ahead of 3D printing and the Internet of Things*

Christy Turlington Burns tries the Apple Watch with Apple's CEO Tim Cook



Global shipments of wearable tech

[in millions]

Smartwatches
Wristbands

Today, the gadgets we carry are becoming less an extension of ourselves, and more and more a *part* of us. "Wearables" are electronic or computing devices that are worn on the body – performing functions like tracking, biosensing and mobile communications – and we're about to see a lot more of them.

The ultimate aim of all wearables is to provide portable, seamless and mostly hands-free access to 'life-enhancing' functions. To date, by far the most successful wearables have been fitness trackers that record things like physical activity, heart rate and sleep quality, but many analysts believe we're on the cusp of a wearables revolution.

That revolution will undoubtedly be spurred on by the launch of one of the most talked-about wearable devices of all time: the Apple Watch. Set for commercial release in April 2015, it has been the subject of much rumour, speculation, hype and even prayers for at least five years. So what can we expect from the must-have gadget of the decade?

The watch was created as a companion device to the iPhone, which means you can make calls, send messages and surf the web right from your wrist once the two devices are paired. It also comes with a slew of sensors to monitor your fitness, and is able to authorise Apple Pay transactions when in contact with its PIN-verified owner's fingerprint. Interaction with the device will feel new too – thanks to a 'digital-crown' dial used to navigate the touchscreen without obscuring it, and a haptic feedback engine that can literally tap you on the wrist.

It's not all good news for wearables, though. Arguably as eagerly anticipated as the Apple Watch was the face-worn optical display Google Glass. Despite prototypes being trialled by early adopters and developers over the last couple of years, it failed to gain traction and, as of 19 January 2015, is on hiatus.

Wearables are pressing ever onward, though. Look out for devices becoming less bulky, less obvious and even implantable. Celebrated futurist Ray Kurzweil – who correctly predicted Wi-Fi and voice commands – reckons that within five years, we'll wear glasses that can beam images direct onto our retinas. He also predicts that by 2045 we'll be able to multiply our intelligence by a factor of a billion by wirelessly linking our brains' neocortexes to the Cloud. Talk about mind-blowing stuff!

"Apple's Watch has been the subject of rumour, speculation, hype and prayers"

How the Apple Watch works

Will it change the face of wearable tech?

The hotly anticipated Apple Watch will finally go on sale 24 April 2015 and there will be 38 different versions available. These include two different face sizes, 38 millimetres (1.5 inches) and 42 millimetres (1.7 inches), to suit smaller and larger wrists, and multiple strap and metal variations. Prices will range from £299 ($349) for the basic Sport model to £13,500 ($17,000) for the top-of-the-range 18-karat gold Apple Watch Edition. In fact, Apple has invented a new kind of gold for its luxury timepiece. Rather than combining three parts gold with one part silver or copper, which are standard metals used in alloys, Apple has used ceramic instead, a low-density material that makes the gold twice as hard and more resistant to scratches.

You can expect to get about 18 hours of typical everyday use out of the Watch between charges, but the battery life can be extended to about 72 hours if you activate the Power Reserve feature that turns most of the functions off. It will then take approximately 2.5 hours to go from zero to full charge when you clip on the wireless charger.

As well as being able to accurately tell the time to within 50 milliseconds via the customisable face, the Watch can also run a variety of other functions when paired with an iPhone 5, 5C, 5S, 6 or 6 Plus. It can be used to make and take phone calls via the built-in speaker and microphone, receive and send text messages by dictating them, selecting from preset templates or simply selecting an emoji, and it can track your fitness using a variety of built-in sensors. However, it can only measure the distance you travel when you have your GPS-enabled phone with you too.

Thousands of apps have also been developed for the Watch, enabling you to access social networks such as Facebook and Instagram, summon a taxi via Uber and identify the name of a song using Shazam. It will also come in very useful when travelling, as you'll be able to use it as your boarding pass at the airport and as your room key when you get to the hotel.

Monitor your heart rate

Behind a set of four sapphire lenses on its back cover, the Apple Watch's custom heart-rate sensor uses infrared and visible-light LEDs and photodiodes to measure your pulse. When light from the LEDs shines onto your wrist, a portion of it is reflected by the blood in the arteries just beneath the skin, and registered by the photodiodes. This reflection increases and decreases as blood volume rises and falls rhythmically with the beating of your heart.

Pay for your shopping

First you need to add your credit card details to the Apple Watch app on your iPhone. When you pay for your shopping, you tap the button on the side of the Watch twice and place the face against the payment terminal. This transmits a unique placeholder code to your bank, which matches it up to the account details you registered. For added security, you need to enter a passcode to unlock Apple Pay functionality each time you put the Watch on.

Detect your movement

Accelerometers measure acceleration, tilt, force and vibration, by means of electrical components that produce voltage in proportion to the physical movement of tiny mobile masses within the device. The Apple Watch uses an accelerometer to detect all kinds of physical movement – from standing up to working out – to monitor your activity levels and track your fitness. It senses when you raise your wrist and the watch responds by displaying the screen.

Tactile sensation

The Taptic Engine is a unique haptic feedback vibrator that lets the Apple Watch deliver physical sensations to your wrist. It gives you a discreet tap when you receive a message, helps you get someone's attention with a remote tap, and even lets you send your own heartbeat to someone who's got it racing. The forces on the skin are created by tiny motors called actuators, which can produce a range of recognisably different sensations for each type of interaction.

THE STATS WATCH THIS

2.5 hours CHARGING TIME

10.5mm THICKNESS

£299 STARTING PRICE

38mm SMALL SCREEN HEIGHT

42mm LARGE SCREEN HEIGHT

TYPICAL BATTERY LIFE 18 hours

DID YOU KNOW? *The Watch doesn't have a built-in camera, but can be used to remotely control your iPhone lens*

Apple Watch under the microscope

Take a top-to-bottom tour of today's hottest wearable device

Customisable appearance
Two screen sizes, 38 or 48mm (1.5 or 1.9in) long; six body materials (including 18-karat rose gold); and six strap types, each with multiple colours.

Digital crown
Rotate to zoom, scroll and navigate precisely without obscuring the screen; push to return to the home screen.

Friends button
Brings up a shortlist of chosen inner-circle contacts.

Induction charger
Safe and free of exposed contacts; uses Apple's MagSafe magnet technology to snap automatically onto the back of the Watch when in range.

Touchscreen
Retina display laminated onto super-hard polished sapphire crystal or Ion-X glass; can distinguish between a light tap and a purposeful press.

Taptic engine
Produces haptic feedback to deliver discreet tactile sensations in conjunction with various notifications and functions.

Battery
A full charge lasts about a day with normal usage.

Custom heart-rate sensor
Visible and infrared LEDs and photosensors work together to read the wearer's heart rate.

Loudspeaker
Used for voice directions and taking phone calls; produces subtle audio cues for alerts and reminders.

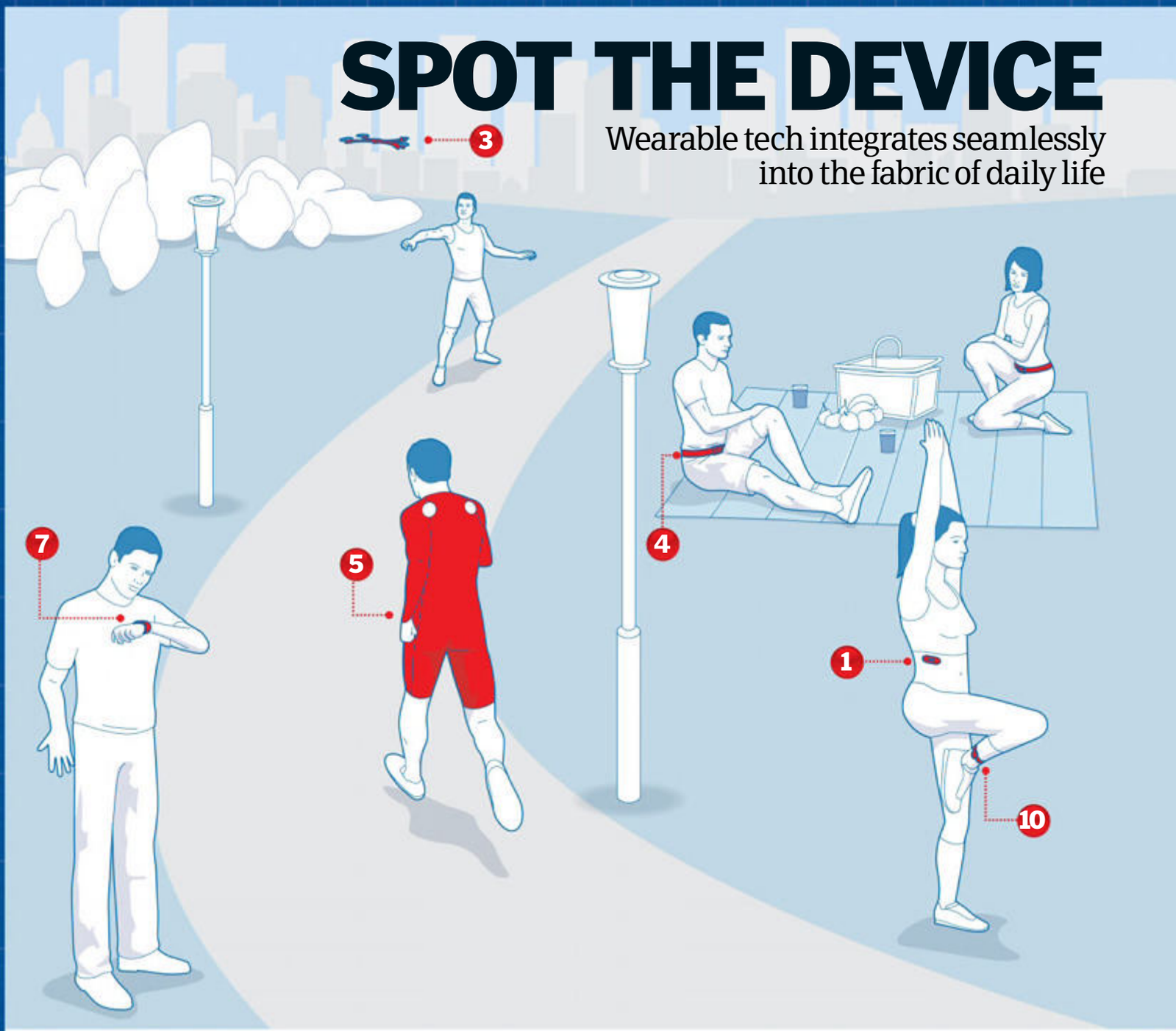
S1 chip
Entire computer system miniaturised into one chip, encased in a resin shell to protect it from the elements, impact and wear.

Touchless payment via Apple Pay will be a feature of the Apple Watch

"Ampstrip is a wearable activity monitor that sticks to the skin of the torso like a plaster"

SPOT THE DEVICE

Wearable tech integrates seamlessly into the fabric of daily life



1 Heart-rate monitor stickers
AmpStrip is a 24/7 wearable heart-rate and activity monitor that sticks to the skin of the torso like a waterproof plaster. Its echocardiogram (ECG) sensor uses a pair of electrodes to capture the timing of electrical signals produced by the heart as it beats, while its accelerometer tracks posture, activity type and intensity.

2 Smart gloves
ProGlove is a sensor-loaded smart glove designed to improve efficiency, performance and safety of factory workers. It performs optical scanning and identification of goods, tools and parts; motion tracking to prevent missed steps in production processes; and heart-rate monitoring to help the wearer avoid physical burn-out.

3 Wearable drone
Taking narcissism to the next level, Nixie is the world's first wearable drone camera. When not in use, its four arms cling to the wrist like a bracelet, but the arms unfold on cue and the Nixie takes flight. Like a boomerang, it arcs through the air taking selfie shots from new dramatic perspectives, leaving the wearer free to pose.

4 Smart belt
The Belty smart belt uses pressure sensors and actuators to tighten or loosen itself to the wearer's preferred level of comfort as their waistline expands and contracts throughout the day. It also houses a pedometer – nudging the wearer if they've been sedentary for too long – and connects with an app for long-term analysis.

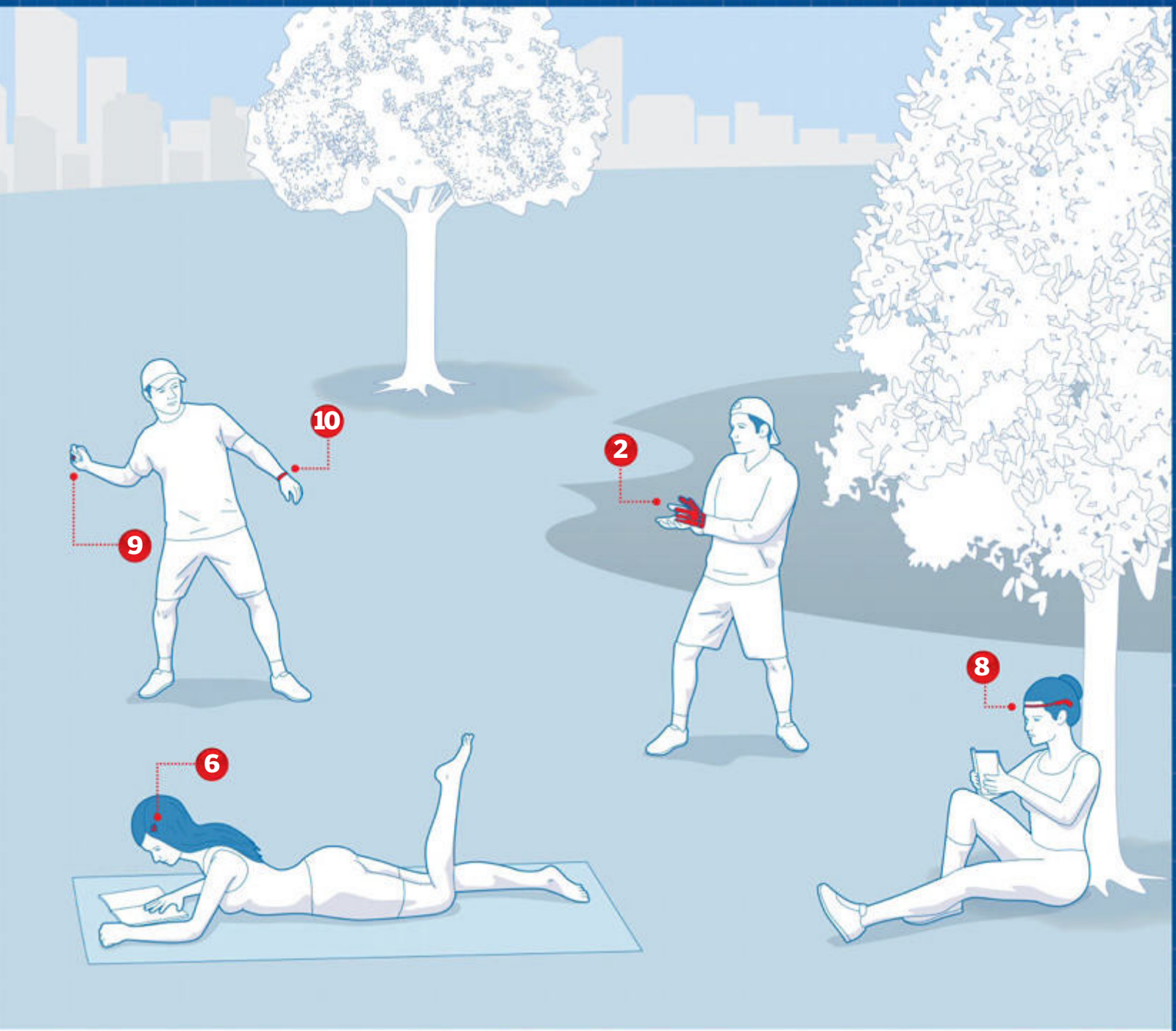
5 Smart fabrics
Smart fabrics give the wearer information about their body movements. XelfleX textiles have optical fibres woven into them, which scatter light differently as the wearer's joints bend and flex. Sensoria socks have pressure sensors that relay information about foot strike to a Bluetooth anklet, and a smartphone app helps wearers improve their running technique.

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Watch a demo of Microsoft's HoloLens!

www.howitworksdaily.com

DID YOU KNOW? *48% of people plan to buy a wearable in the next year, and 20% already own at least one device*



6 UV hairclip
The Solitair app analyses a person's natural pigmentation from a picture of their skin and combines this with geographical location and weather forecast data to give an individual daily recommendation for safe Sun-exposure time. A UV sensor, worn in the hair or on a lapel, registers exposure and alerts the wearer when it's time to seek shade.

7 Smartwatch
Samsung's Gear S smartwatch is a giant curved watch and smartphone in one. Just like a phone, it has its own 3G service and SIM card, and wearers can make hands-free calls either by speakerphone or via a Bluetooth headset. It also supports messaging, email, fitness monitoring, news blasts, maps and apps.

8 Brain-sensing headband
Muse is a brain-sensing headset that measures electrical brain signals via a set of seven electroencephalography (EEG) sensors positioned around the band. Users can study their brain in real-time, as they perform exercises designed to increase focus, reduce stress, or improve their ability to keep calm under pressure.

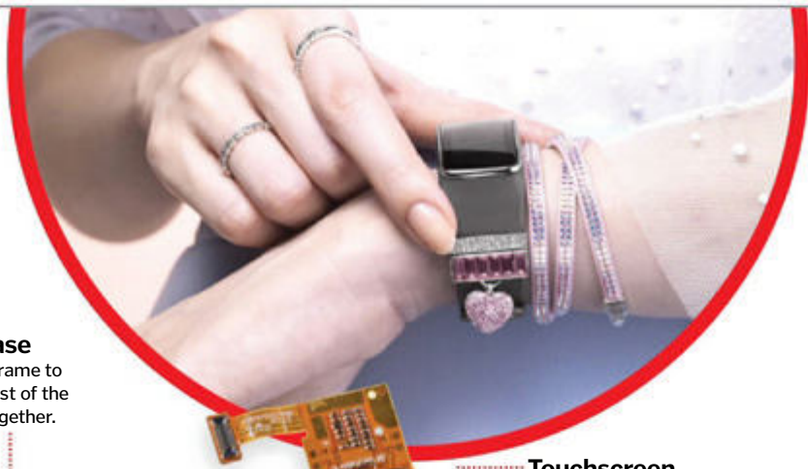
9 Smart ring
The Mota smart ring keeps smartphone notifications at its wearers' fingertips, even when their phones are not. The ring pairs to the wearer's phone via Bluetooth, and flashes up important notifications in the form of subtle text, audio or tactile alerts, leaving the wearer to decide whether to interrupt what they're doing to respond.

10 Fitness tracker
Moov is a unique nine-axis motion-sensing system that maps the wearer's movements, offering suggestions for improved pace and body positioning in sports from swimming to cardio boxing. Its disc-shaped body houses a magnetometer, gyroscope and accelerometer, and it can be strapped to a wrist, ankle, shoe, or bike pedal.

"EMG sensors read and respond to the electrical activity generated in the muscles of your forearm"

Inside the Samsung Gear Fit

The personal trainer that's always on hand to help you achieve your fitness goals



Motherboard
The brains of the operation; includes a six-axis accelerometer, gyroscope, microcontroller, processor and flash memory.

Wireless communicators
Combined Wi-Fi/Bluetooth/FM receiver chip and antenna exchange information with coupled smart devices.

Inner case
Acts as a frame to hold the rest of the goodies together.

Wrist strap
Interchangeable flexible plastic band comes in a variety of colours, so you can match it to your outfit or mood.

Touchscreen
Curved Super AMOLED (active-matrix organic light-emitting diode) 1.84in touchscreen display with a resolution of 128 x 432 pixels.

Display
Customisable colour display delivers alarms, emails, calls, texts and app notifications, so you can stay in the loop while you work out.

Metal bumper
Keeps the battery and motherboard separated.

Battery
Curved to fit snugly into the overall design; holds charge for up to four days.

Unibody case
With integrated charging connectors and square cutaway to let the heart-rate monitor "see" the skin of the wrist.

Gesture-control armband

Reimagining the ways you grapple with your digital world

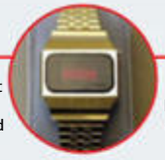
The Myo armband literally listens to your muscles talking. An expandable armband made up of eight muscle-sensing modules, its suite of medical-grade EMG (electromyography) sensors reads and responds to the electrical activity generated in the muscles of your forearm as you produce different gestures – including squeezing and rotating your fist, waving your hand, spreading your fingers and pointing.

While it's hard to call Myo a hands-free device, it *is* touch-free, letting you do stuff that would otherwise involve connecting physically with controls or a computer. Its creators are connecting with developers to come up with applications from gaming and audio-video playback control, right through to sign-language interpretation and controlling lighting at concerts.

KEY DATES
HISTORY OF WEARABLES

1961
The first wearable electronic computer, used with a secret in-ear radio receiver, is invented as roulette players' cheating aid.

1972
Hamilton introduces the first LED digital wristwatch, the Pulsar. It has an 18-karat gold body and retails for $2,100.



1983
The first experimental digital hearing aid is made, comprising a behind-the-ear processor and an in-ear microphone.

2000
The first wireless Bluetooth headset is used as a way to speak hands-free on a mobile phone.

2008
The Fitbit Classic activity and sleep tracker is released, setting the benchmark for the early consumer wearables market.

DID YOU KNOW? *31 per cent of European businesses plan to introduce wearable tech in the workplace in 2015*

ON THE HORIZON

Hop aboard our time machine to see the wearables you'll be sporting in the future

Digital tattoos

Our first step toward cyborgdom: embedded smart tattoos

Project Underskin – brainchild of NewDealDesign, creator of the FitBit and other wearables – is a glowing tattoo embedded just underneath the skin of your hand. The device is powered by your body's electrochemical energy and performs tasks in response to your hand gestures. Its capabilities include unlocking doors and exchanging data using NFC (near-field communication) signals, displaying notifications in the form of light patterns under the skin, and monitoring medical metrics such as blood-sugar levels.

Microsoft HoloLens

Experience your surroundings differently with the world's first holographic computer

Microsoft's HoloLens is a headset with transparent holographic lenses and spatial sound, which allows you to 'pin' holograms – or virtual images – to the view of your physical surroundings. Unlike virtual reality, where you're immersed in a completely computer-generated world, HoloLens lets you experience a mixed reality, where digital aspects blend seamlessly with the physical world, and you interact with your digital content – apps, information, game elements – in the physical space around you.

Touchscreen arms

Finally, a display immune to fumbling, dropping and shattering

On first glance, the Cicret (pronounced "secret") looks like any standard fitness band, but one twist of your forearm reveals its biggest secret: a picoprojector casts an image of your smartphone's user interface directly onto your arm, turning your skin into a touchscreen! An array of eight long-range proximity sensors tracks the position of your finger as it reflects their laser output. Cicret works on all skin colours, even in bright daylight.

Hi-tech fashion

Tech and couture collide in environmentally responsive catwalk pieces

So long, little black dress. British designer Rainbow Winters produces one-of-a-kind garments whose aesthetic shifts and changes in response to environmental stimuli. Her designs include dresses made from specially dyed fabrics that change colour, glow and animate according to ambient noise, sunlight, water, UV club light and music. Winters also works with fabrics that change colour in response to stretching and twisting, as they diffract light differently under these forces.

Google Glass looks to the future

Google Glass is an optical display visor with the functionalities of a smartphone, which you wear on your face like a pair of glasses. To create Glass's display, a projector in one of its arms shines images into a small prism that protrudes into the top corner of your field of vision. The prism bends the projected light toward your eye so that when you glance at it, the image appears to hover over the physical world beyond.

Wearing Glass, you can make calls, exchange messages, get directions, surf the web, shoot photos and videos, and track your workout, all hands-free. Commands operate via blinks, voice commands and – when desired – a slim touchpad integrated into one of the device's arms.

Glass was withdrawn from the marketplace in January 2015 due to lacklustre public opinion, but Google clearly intends to develop a Glass 2, if its website is anything to go by: "The journey doesn't end here. You'll start to see future versions of Glass when they're ready (for now, no peeking)."

Glass's display is the equivalent of a 63cm (25in) HD display from 2.5m (8ft) away

"Both men and women's hair is as hard as copper wire of equal thickness"

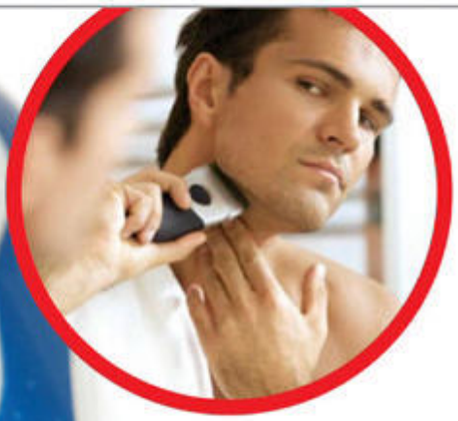
Electric razors explained

How these spinning blades cut hair, not skin

Body hair is tough; both men and women's hair is as hard as copper wire of equal thickness, so any razor we use needs an effective cutting mechanism. Electric razors use either a foil or rotary system. Foil shavers contain oscillating blades beneath a thin, steel, perforated foil. The foil functions to lift hair toward the blades, helping the user obtain a very close shave.

Rotary razors have circular blades that cut by spinning. The blades can typically flex within the shaver, allowing easier access to curved areas than other razors. The rotary razor works best with a circular motion, which encourages hair to slip into the razor head gaps.

Which to go for depends as much on personal preference as it does on functionality, but you are far less likely to incur a life-threatening injury from either one compared to the cut-throat razors of old.



The rotary electric razor

Take a closer look at how a rotary electric razor deals with our varied hair growth

Easy access
This button releases the razor's head, allowing the user to clean the razor and remove the collected trimmings.

The body
The razor's body is lightweight and easily manoeuvrable, housing the rechargeable battery and motor system.

Long hair slits
These slits target the longer hairs, forcing them toward the razor's blades.

Short hair gaps
These small circular holes target short hairs, and vary slightly in size to compensate for varied hair length.

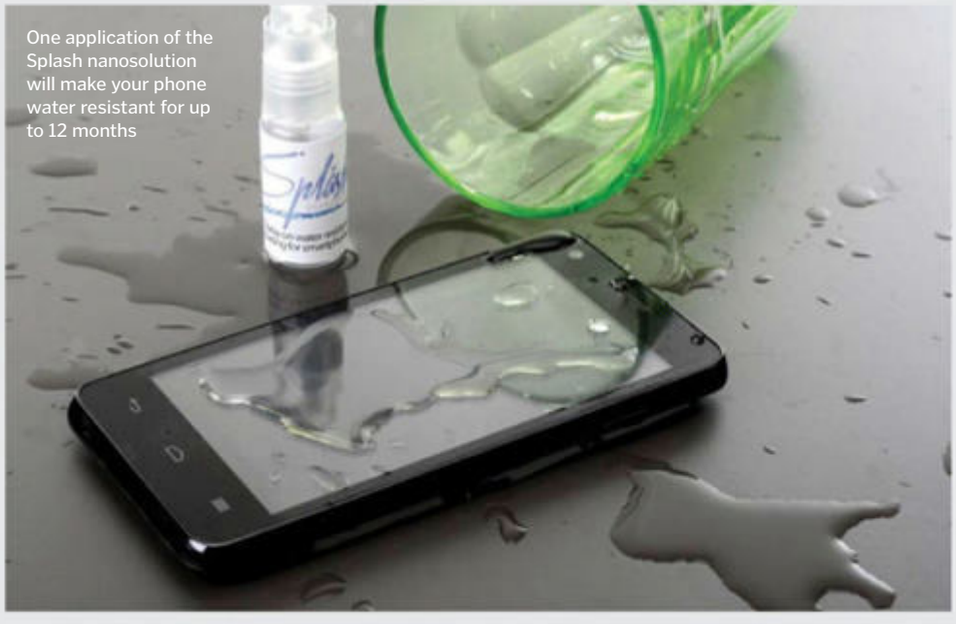
Three blades
Typically a rotary shaver has three blades in a triangular structure, providing a large surface area.

Ergonomic flexing
The three blades are able to flex up and down within the razor, allowing effective shaving of curved areas.

Waterproof your phone

How this amazing spray makes your phone water resistant

Accidentally spilling a glass of water over your phone can cause irreversible damage to the inner workings of the device. Of course, you could attach a waterproof case to make sure it is fully protected, but these often add a lot of bulk to your otherwise slim and sleek phone. However, now you can simply spray on an invisible water-resistant coating that is 1,000 times thinner than a human hair. Splash spray uses nanotechnology to create a small barrier of air around the phone to repel water molecules away from the surface and prevent them from getting inside. All you have to do is spray the openings and buttons on your phone and repeat the process three times, then spray a microfibre cloth and use it to buff the front, back and sides to remove any residue. The spray dries in ten minutes and makes your phone water resistant straight away. It will only protect your phone from spillages, though. Fully submerging your device will still allow liquid to enter the housing, causing damage to the elements inside.



One application of the Splash nanosolution will make your phone water resistant for up to 12 months

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"Early planetariums simply had paintings of the night sky on the inside of the dome"

Planetariums

The incredible theatres where you can explore the night sky and beyond

You no longer need to train for several years as an astronaut to explore space, as planetariums can give you an amazing virtual tour of the universe while you keep your feet firmly on the ground. Instead of a big cinema screen at the front of the room, images are projected onto a domed ceiling to create a more immersive experience.

"There's no edge to the screen so it's like you're actually there," says Jenny Shipway, Head of the Winchester Planetarium in the UK. "During a show you shouldn't be aware of the dome at all, the dome should be invisible so your brain can imagine you are actually in this three-dimensional virtual universe."

Early planetariums simply had paintings of the night sky on the inside of the dome to give people a clear view of all the constellations. However, when projectors were developed they could depict moving celestial objects as well as fixed stars, and represent views from different points on the Earth's surface too. Traditional planetariums use mechanical star ball projectors, but they are limited to showing the stars and planets that can be seen from Earth.

The most modern planetariums now use digital projectors hooked up to computers instead, and can project any image onto the dome to show incredible views from anywhere in the universe. Combining data from space agencies, spacecraft and telescopes all over the world, realistic graphical representations of entire galaxies can be projected onto the dome.

"We use software called Uniview and it has a virtual model of the known universe in it", says Shipway. "We use it as a flight simulator. It's literally like playing a computer game; just using a computer mouse you can fly anywhere. You can do a seamless zoom all the way out from Earth right to the edge of the visible universe."

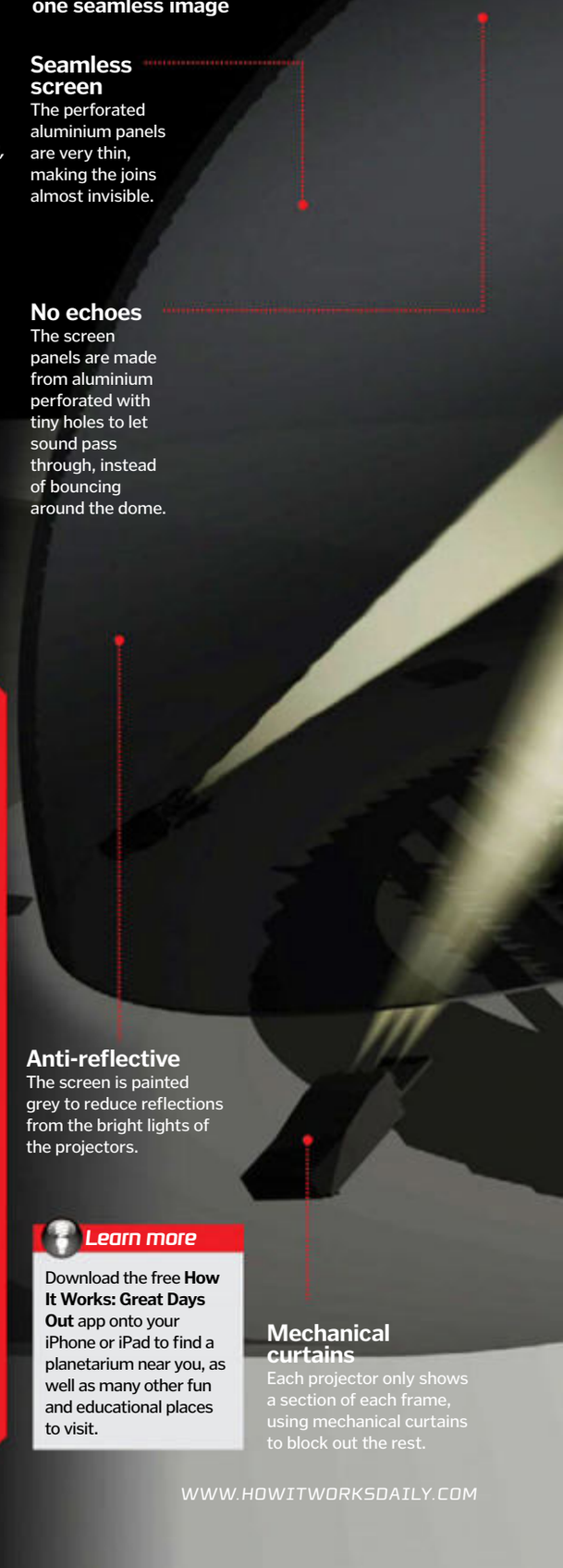
A star ball projector can only show the view from one hemisphere

Star-ball projectors

Some planetariums still use traditional analogue projectors known as star balls. These metal spheres sit in the middle of the audience and have a bright electric lamp inside that shines light through several small lenses surrounding it. The lenses are used to represent stars, focusing light onto the planetarium dome to recreate the night sky as it can be seen from Earth. Single star balls are often fixed at one end so can only show the view from one hemisphere. However, many projectors feature two star balls attached together in a dumbbell-shaped structure so that they can represent the view from anywhere on Earth. Additional moving projectors can also be attached to show moons, planets and other moving celestial objects. The main limitation of star-ball projectors is that they can only show the view from Earth, while digital planetariums let you explore the far reaches of the universe too.

Inside a modern planetarium

How several projectors work together to create one seamless image



Seamless screen
The perforated aluminium panels are very thin, making the joins almost invisible.

No echoes
The screen panels are made from aluminium perforated with tiny holes to let sound pass through, instead of bouncing around the dome.

Anti-reflective
The screen is painted grey to reduce reflections from the bright lights of the projectors.

Mechanical curtains
Each projector only shows a section of each frame, using mechanical curtains to block out the rest.

Learn more

Download the free **How It Works: Great Days Out** app onto your iPhone or iPad to find a planetarium near you, as well as many other fun and educational places to visit.

8K x 8K

HIGHEST-RESOLUTION 3D PLANETARIUM

The planetarium at the Macao Science Center in Macau uses 12 projectors to display an 8,000 x 8,000-pixel 3D image. That's twice as many pixels across as ultra-HD 4K resolution!

DID YOU KNOW? *When a bulb is replaced in one of the digital projectors, the entire system needs to be recalibrated*

Hanging screen
The screen is attached to a metal frame that hangs from the roof and is tilted for a more comfortable viewing experience.

Calibration
The projectors need to be lined up perfectly with the same brightness and contrast settings to create one seamless image.

One image
The image sections from each projector blend in with the images from neighbouring projectors to create one big image.

Projectors
A series of digital projectors are positioned around the edge of the inside of the dome.

Pilot's desk
The planetarium shows are controlled from the pilot's desk at the back of the room using a tablet and computer.

Fish-eye lens
Each projector has a fish-eye lens, which distorts the image to stretch it across the curved dome surface.

Reclining seats make it much more comfortable to view the action overhead

A main server controls the footage displayed by the projectors

"Hawking's PC uses an interface called EZ Keys, which scans across the on-screen keyboard"

Stephen Hawking's wheelchair

The technology that empowers the world's most famous physicist

Stephen Hawking was diagnosed with amyotrophic lateral sclerosis (ALS) when he was 21. ALS is a form of motor neurone disease, which results in the progressive death of the nerves that control the muscles. Most sufferers die within five years, but fortunately for physics, and for Professor Hawking himself, his disease has progressed extremely slowly. Even so, at the age of 73, Hawking has just a small amount of motor function left, mainly in the muscles of his face. His link to the world is provided by the computer technology built into his wheelchair.

Incredibly, Professor Hawking controls all the functions of his Windows tablet PC using just a single switch – imagine operating your PC using nothing but the spacebar! Hawking's PC uses a special interface called EZ Keys, which scans across each letter of the on-screen keyboard, one at a time. When Hawking moves his cheek, a sensor detects the movement and the computer halts the scanner and picks that letter. He can also use this process to scan from one button or menu item to the next, and so control his email program (Eudora), web browser (Firefox) or even make calls over Skype.

As Hawking's physical condition gradually deteriorates, his typing speed has dropped to just one or two words per minute. Scientists at Intel compensate using algorithms tailored to Hawking's vocabulary and writing style, which accurately predict which words he will want to use next.

"We're all pretty disabled on the cosmic scale. What difference is a few muscles more or less?"
– Stephen Hawking

Chair of physics

How talking tech works to give Stephen Hawking a voice

IR sensor
A tiny infrared sensor mounted on his glasses detects when Hawking moves his cheek muscle.

Speech synthesiser
A hardware synthesiser on the back of the chair translates written text into Hawking's distinctive electronic voice.

12" display
The daylight-readable screen allows Professor Hawking to compose lectures, check his email and even use Skype.

Tablet computer
A Lenovo ThinkPad X230t with a Core i7 processor controls all the systems on the chair.

Universal remote
An infrared remote can operate TV, music, lights and even the doors, both at work and at home.

Peripheral box
Contains a USB hub, audio amplifier and voltage regulators for the different subsystems.

Power
The computer system takes power from the wheelchair batteries under the seat and has its own backup battery too.

Thought-controlled wheelchairs

When you speak, your brain sends nerve signals to your throat, even if your muscles aren't strong enough to actually make audible sounds. In fact, this subvocal speech happens even if you just think the words in your head. Technology originally developed at NASA Ames Research Center is now available as a way for severely disabled people to control a motorised wheelchair or send their thoughts to a speech synthesiser. The user wears electrodes stuck to the skin of their throat and simply thinks command words such as 'go left' or 'stop'. The tiny electrical impulses are detected and decoded and the right command is sent to the wheelchair. Hawking has tried brain interfaces like this but they are still too inconsistent for him. At the moment, slight shifts in the placement of the electrodes can see the recognition rate drop from 94 per cent to less than 50 per cent.

Electrodes can sense the signals produced when you speak in your head and recognise your commands

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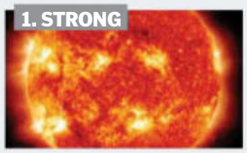
25 FACTS YOU NEVER KNEW ABOUT GRAVITY

Discover the secrets of the fundamental force that holds entire galaxies together

Your weight changes as you accelerate

1 Earth's gravitational pull compels you toward the centre of the planet, but the ground is in the way; it pushes up against you, matching the force exactly. It is this push that makes you feel heavy. As you accelerate to the top of a roller coaster, the chair pushes harder against your body, opposing the force of gravity and making you feel heavier. Once you reach the top and the coaster starts to accelerate downward, your body naturally wants to continue moving upwards. The chair pulls away from your body, and you feel lighter. As the coaster car continues to drop, the support of the chair is removed completely, and you feel momentarily weightless before descending. These indirect changes in weight are known as 'g-force'.



1. STRONG

Stars
In order to escape the gravitational pull at the surface of the Sun, you would need to be travelling at speeds of over 600km/s (373mi/s).

2. STRONGER

Neutron stars
To escape from the surface of a dense neutron star you would have to travel at around 100,000km/s (62,137mi/s).

3. STRONGEST

Black holes
Even light travelling at almost 300,000km/s (186,411mi/s) cannot escape the gravitational pull of a black hole.

DID YOU KNOW? *Gravity accelerates falling objects toward the Earth at a rate of 9.8m/s² (32.2ft/s²)*

Without gravity your body starts to go wrong

2 Our bodies evolved on the surface of the Earth and are optimised to function in Earth's gravity, but in microgravity our systems cannot function normally. If there is no weight on our load-bearing bones, the body starts to remove calcium, and if we stop using the muscles that support our backs and legs, they become weaker.

Astronauts need to exercise in space to minimise the effect microgravity has on their muscles and bones

You would feel weightless at the centre of the Earth

3 Hypothetically, if you dug a tunnel from one side of the Earth to the other and jump in, you would accelerate toward the centre, reaching a speed of around 7,900 metres (25,919 feet) per second. In the centre, you would be momentarily weightless, but inertia would continue to carry you through the tunnel. You would then decelerate as you exited, emerging from the other end 42 minutes later.

Fish have stones in their heads that tell them which way is up

4 Plants and animals have evolved amazing ways to sense Earth's gravitational pull. In the sea, bony fish have floating calcium carbonate deposits in their heads called 'earstones', which are pulled down by gravity. On land, plants have starch grains in their root tips, which sink toward the ground, helping to guide their roots downward.

You can still feel 90 per cent of Earth's gravity on the International Space Station

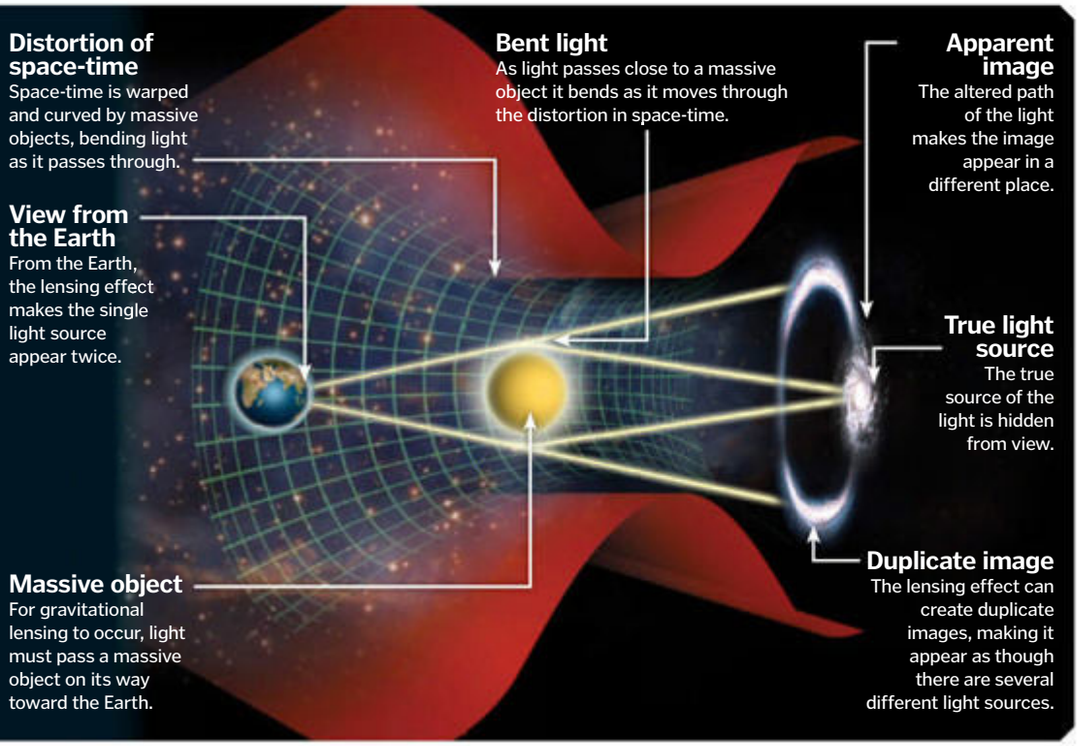
5 The International Space Station orbits Earth at an altitude of between 320 and 400 kilometres (200 and 250 miles), but although astronauts and cosmonauts living inside feel weightless, they are still under the influence of microgravity. The gravitational pull of the Earth keeps the space station in orbit, but it is travelling so fast that it never falls back down to the ground; the astronauts feel weightless because they are in constant freefall around Earth.

"Gravity is only strong over short distances, but dark energy is thought to be spread evenly"

Gravity can bend light

6 If a large collection of matter lies between the Earth and a light source, the path of the light curves as it travels toward us, creating smears, multiple images, or even a complete Einstein Ring. This is known as gravitational lensing and is down to the effect mass has on the fabric of the universe.

Einstein explained that gravity is the result of massive objects distorting the fabric of space-time, a bit like bowling balls sitting on a sheet of rubber. As light travels past a massive object, it is forced to travel around the curve and its path becomes bent.



Quantum mechanics and gravity don't mix

7 Einstein's theory of general relativity tells us how the universe works on a large scale, while quantum mechanics explains how atoms, molecules and fundamental particles interact. The trouble is the two ideas don't fit together. Reconciling the two theories is one of the biggest challenges facing modern physics.

Fermions

Matter particles
Matter is made up of fermions, a combination of six quarks and six leptons.

Quarks

u c t
d s b

Leptons

ν_e ν_μ ν_τ
e μ τ

Gauge bosons

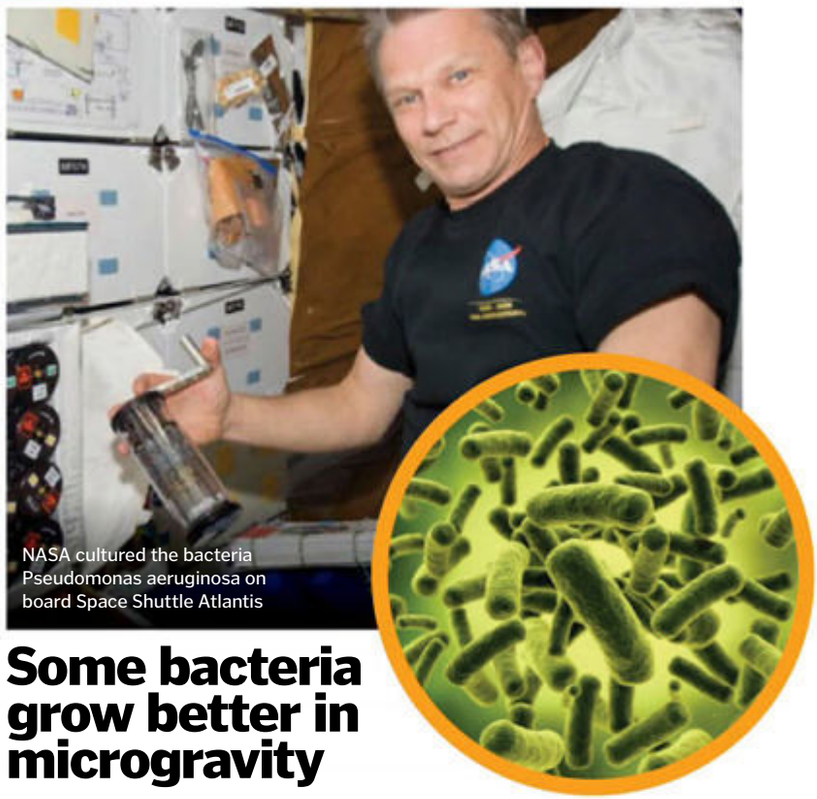
Force carriers
Three of the four fundamental forces are carried by elementary particles called bosons.

Photon
The electro-magnetic force is carried by photons.

Gluon
The nuclear strong force is carried by gluons

Z and W bosons
The nuclear weak force is carried by Z and W bosons

Gravity Gravity is missing from the Standard Model of particle physics.


NASA cultured the bacteria Pseudomonas aeruginosa on board Space Shuttle Atlantis

Some bacteria grow better in microgravity

8 Colonies of bacteria grown on board a NASA Space Shuttle behaved very differently to identical bacteria grown on Earth. They stuck together in shapes never seen on the ground and managed to survive in much higher densities. Understanding these changes could help protect astronauts from dangerous bacterial biofilms during long-term space flight.

KEY DATES
THE SCIENCE OF GRAVITY

Pre-1500
People accept the Greek philosophy that planets and stars follow 'natural motion' and are part of the realm of the gods.

1564-1642
Galileo Galilei observes the Solar System via telescopes, providing evidence for Copernicus' idea that the Earth moves around the Sun.

1571-1630
Using data gathered by Tycho Brahe, Johannes Kepler demonstrates the planets travel in elliptical orbits.

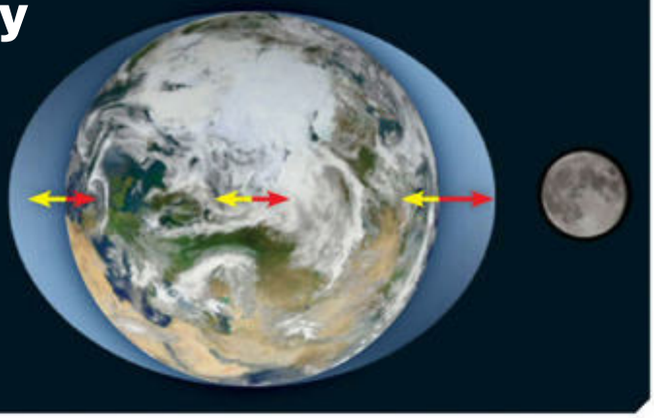
1687
Building on the work of Galileo and Kepler, Sir Isaac Newton publishes his book Principia, describing his theory of gravity.

1915
Albert Einstein publishes his general theory of relativity, explaining gravity is the result of the curvature of space-time.

DID YOU KNOW? *There is a supermassive black hole at the centre of almost every large galaxy, including our own*

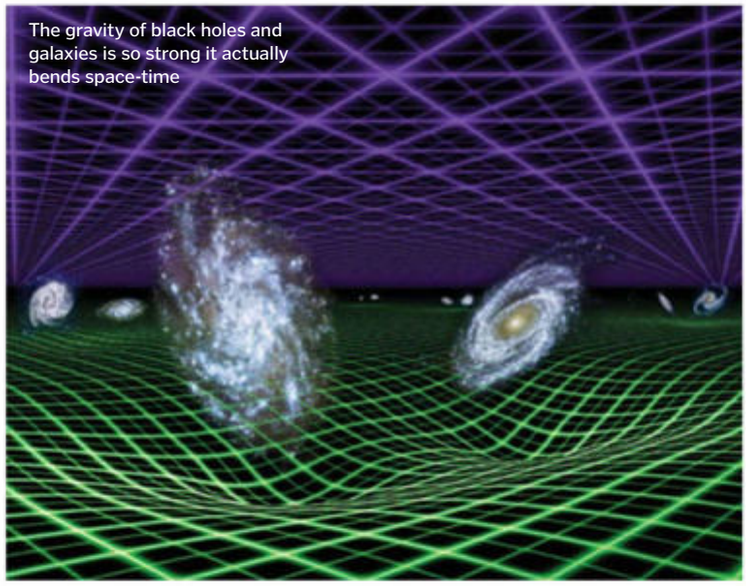
The Moon's gravity makes Earth's oceans bulge

9 The gravitational pull of the Moon has a noticeable effect as it tugs at the Earth; it pulls on the water, causing the oceans to bulge. As Earth and the Moon orbit together, water on the opposite side of the planet also bulges outward, thanks to centrifugal force. As the Earth spins on its axis, these bulges move, causing tides.



Dark energy works against gravity

10 Gravitational attraction is not powerful enough to hold the universe together indefinitely. The universe has been expanding since the Big Bang, and the pull of gravity is being opposed by so-called dark energy. Gravity is only strong over short distances, but dark energy is thought to be spread evenly, causing the expansion of the universe to accelerate, and preventing gravity from pulling everything back together.



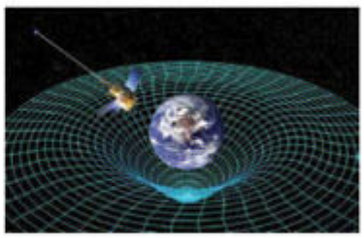
The gravity of black holes and galaxies is so strong it actually bends space-time

Extreme gravity can tear whole star systems to pieces

11 When a massive star dies it leaves behind a remnant core with so much mass that it collapses under the force of its own gravity, creating a black hole. Black holes have such a strong gravitational pull that not even light can escape. They can tear nearby stars to pieces and completely shred their component atoms.

Newton wasn't hit by an apple

12 Sir Isaac Newton's big idea about gravity was not prompted by a knock on the head. Just seeing an apple fall to the ground was enough to get him thinking.



Gravity is not a force

13 According to Einstein, gravity is not really a force at all. The fabric of space-time is bent by massive objects, distorting the paths of other objects – a phenomenon we see and feel as gravity.

Gravity is one-directional

14 Magnets can both attract and repel, but gravity only works in one direction. It compels massive objects to come together, but cannot be reversed to force them apart.

The range of gravity is infinite

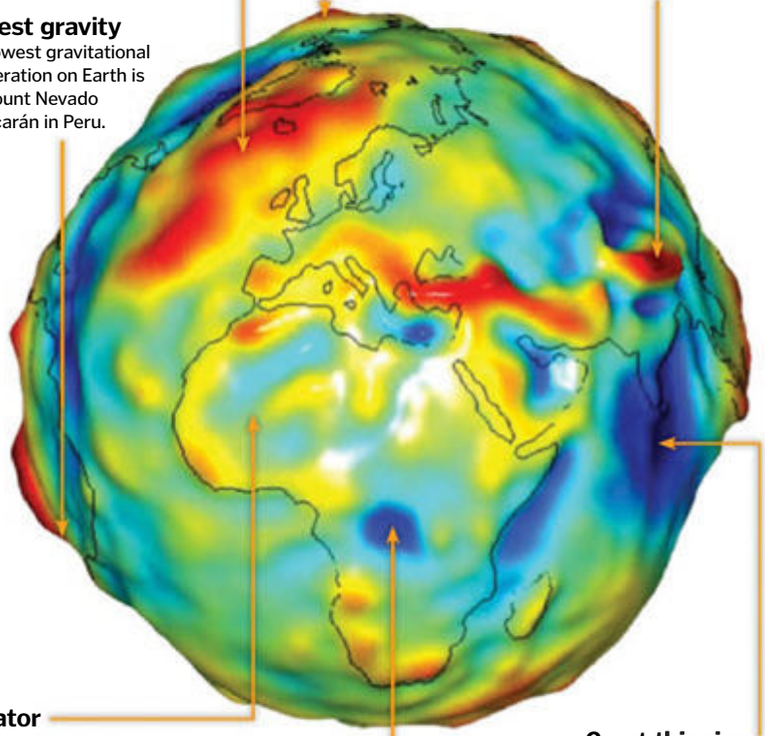
15 Gravity might be the weakest of the four fundamental forces, but has unlimited range. Its strength decreases rapidly as objects move farther apart, but its reach is theoretically infinite.

"In Ancient Greek philosophy, Aristotle taught that all objects moved toward their 'natural place'"

Earth's gravity is lumpy

16 It is clear by looking at mountains and valleys that Earth is not a perfect sphere, and beneath the surface, the distribution of rocks and minerals is uneven, creating pockets of varying density, and therefore varying gravity.

NASA has been probing Earth's gravity using two GRACE satellites. As the first satellite approaches a dense region, it is pulled forward, racing ahead a bit, and as it moves past, it is pulled backward. By measuring the distance between the two, detailed gravity maps are produced.



Mid-Atlantic Ridge
This stronger spot is down to a mountain range beneath the Atlantic Ocean, where the Eurasian and North American tectonic plates meet.

Highest gravity
The highest gravitational acceleration on Earth is at the surface of the Arctic Ocean.

Himalayas
Some areas of high gravity are the result of surface features like the Himalayas.

Lowest gravity
The lowest gravitational acceleration on Earth is on Mount Nevado Huascarán in Peru.

Equator
The spin of the Earth creates a bulge at the equator, raising the surface away from the centre of the planet and decreasing the gravitational pull.

Tiny variation
If you fell from a height of 100m (328ft) at the point with the lowest gravity on Earth compared to the highest, you would only fall for an extra 16 milliseconds.

Crust thinning
In regions where tectonic plates are moving apart, the Earth's crust is thinner, leading to gravitational weak spots.

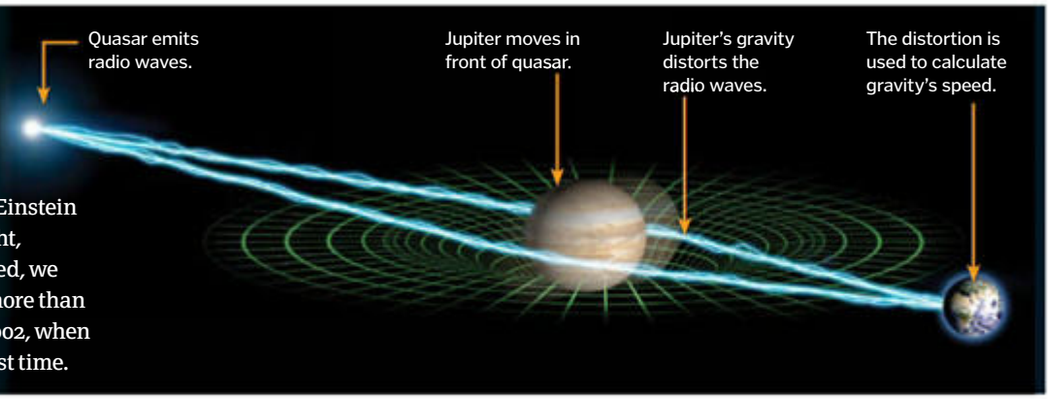
Aristotle noted that most objects naturally fall towards the centre of the Earth

Newton and Einstein aren't the only people to have wondered about gravity

17 Gravity has been pondered by some of the world's greatest minds. In Ancient Greek philosophy, Aristotle taught that all objects moved toward their 'natural place'; some, like stones, would be drawn to the centre of the Earth, others, like steam, would be attracted upward toward the heavens.

Gravity travels at the speed of light

18 According to Newton's theory of gravitation, the pull of gravity is instantaneous, but according to Einstein the effects of gravity travel at the speed of light, meaning that if the Sun suddenly disappeared, we would continue to orbit an empty space for more than eight minutes. This idea was confirmed in 2002, when the speed of gravity was measured for the first time.



134.368KM/H

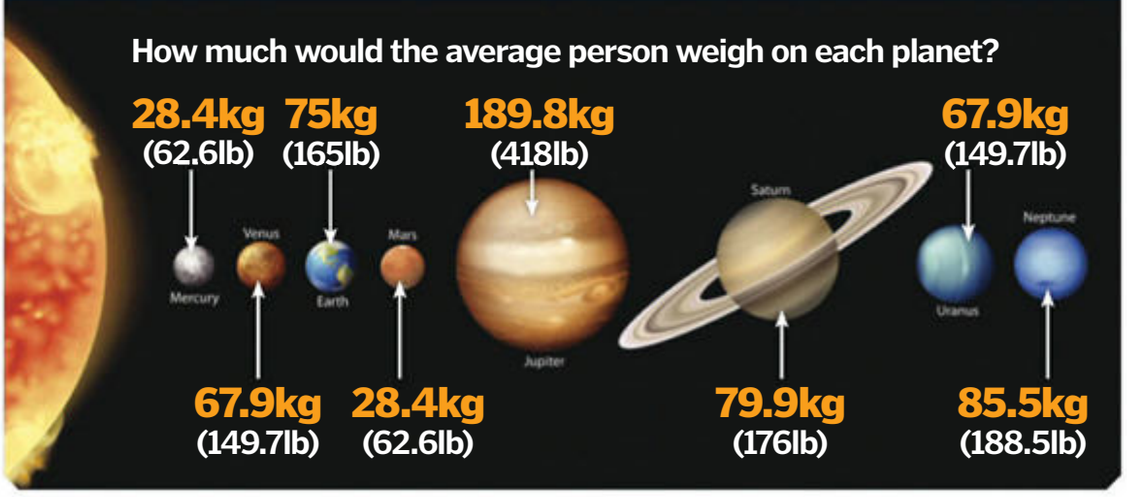
FASTEST SPEED ON A GRAVITY-POWERED SNOW SLED

In 2014, Guy Martin broke the world record for the fastest speed on a downhill toboggan. Powered entirely by gravity, he reached an incredible 134.368km/h (83.49mph).

DID YOU KNOW? *A clock in a strong gravitational field runs slower than a clock in a weaker gravitational field*

You weigh almost three times more on Earth than you would on Mars

19 Mass is a fixed property based on all of the atoms that make up your body; it is always the same, whether you are on Earth, inside the International Space Station, or standing on the surface of the Moon. Your weight is the force of gravity acting on your mass, and is defined as mass multiplied by the acceleration due to gravity. On other planets, the gravitational pull is different, so although your mass is exactly the same, your weight would change.




Spacecraft use the gravity of planets to slingshot around them and increase their speed

Gravity can be used to make a space slingshot

20 It takes an enormous amount of energy to send spacecraft to the far reaches of the Solar System, so space agencies use a technique called a 'gravity assist' to help. Instead of heading straight for the target, spacecraft loop around and fly past a planet like Earth, Mars or Jupiter, using their orbital momentum as a boost.

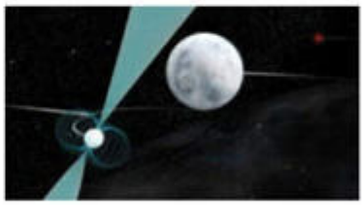
how it works

Earth's gravitational pull is actually weaker than the pull of a fridge magnet

21 Gravity is the weakest of the four fundamental forces. The entire gravitational pull of the Earth cannot compete against the nuclear strong force, which holds the nuclei of atoms together. It cannot oppose the electromagnetic force that holds a magnet onto your fridge and it cannot stop the nuclear weak force, which is responsible for radioactive decay.

Astronauts practice weightlessness in aeroplanes

22 Aeroplanes can perform a swift up-and-down motion called a parabolic arc to induce a brief period of weightlessness, allowing people to train for space travel.



Scientists study gravity in cosmic laboratories

23 One of the best places to study gravity is in the ready-made laboratory of outer space. Observing closely orbiting pairs or trios of neutron stars and white dwarfs enables scientists to measure the effects of gravity.

Spinning creates artificial gravity

24 On a spinning fairground ride, the outer walls provide an inward centre-seeking force that keeps people travelling in a circle. This is called centripetal force, and the effect feels just like gravity.

Massive objects make gravitational waves when they move

25 According to Einstein's theory of relativity, massive objects warp the fabric of space-time. When these objects move they create ripples, much like a water boatman skating across a pond.

"The body's first response after you've been submerged in cold water is to slow the heart rate down"

How does popping candy work?

Discover the science behind this sweet's sizzling sensation

Pop Rocks candy bounces in your mouth when high-pressure carbon dioxide bubbles are released as it melts on your tongue

Popping candy explodes on the tip of your tongue, a sensation either loved or loathed by those with a sweet tooth. The secret to its unique fizz, crackle and pop is actually all down to how it is made.

In fact, popping candy is created in a similar way to traditional boiled sweets. Sugar, corn syrup, water and flavouring are all mixed together and then heated so that the water boils off. If the resulting sugar syrup solution would be left to cool at this stage, you'd end up with regular hard sweets. But in order to give the candy its unique popping potential, the molten mixture is exposed to high-pressure carbon dioxide gas at about 40 times atmospheric pressure. This causes small bubbles of gas to form within the solution. As this is then cooled, the pressure is released, causing the candy to shatter into small pieces of rock. However, each piece still contains tiny high-pressure bubbles. When you then place the candy on the tip of your tongue, and it begins to melt, the trapped pressurised bubbles are released, creating a unique sizzling sound and the sensation of it bursting and bouncing around your mouth.

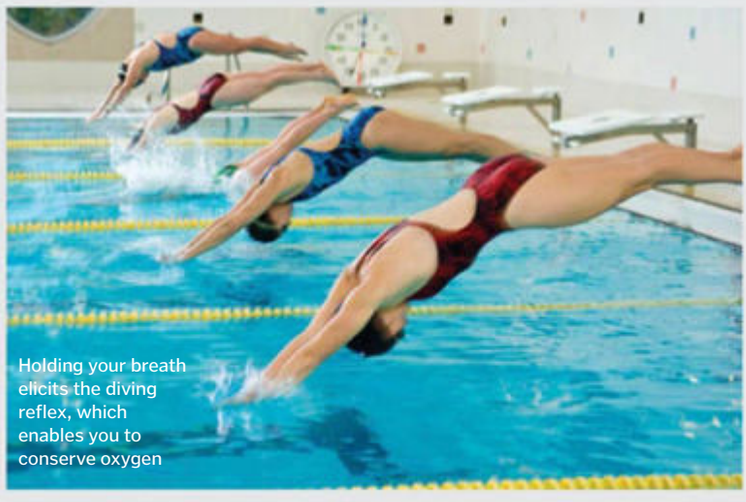
How the diving reflex works

Find out how it enables you to swim underwater

The diving reflex is a physiological response that enables all mammals, including humans, to dive underwater for extended periods of time on just one breath. Once triggered, it slows and shuts down parts of the body in order to conserve energy and ensure survival.

It all happens in stages. The body's first response, after you've held your breath or been submerged in cold water, is to slow the heart rate down, known as bradycardia. This enables more oxygen to reach the organs, as less is needed in the bloodstream. Eventually the body's circulatory system will start to constrict your capillaries, redirecting blood from the extremities, so that more is allocated to the vital organs such as the heart and brain.

At this stage you're likely to experience cramping in your arms and legs, due to a lack of oxygen in these areas. The latter stage, blood shift, generally only occurs if you're free-diving at depths of a few hundred feet. This essentially causes the lungs to fill with plasma, helping to prevent them from collapsing under the pressure.



Holding your breath elicits the diving reflex, which enables you to conserve oxygen

RECORD BREAKERS
CARD COUNTING

59 PACKS OF CARDS MEMORISED

In 2007, David Farrow broke the world record for the most decks of playing cards memorised in a single sighting, recalling a total of 3,068 cards.

DID YOU KNOW? *Short-term memories are often stored as audio, which is why we repeat things we want to remember in our head*

Short-term memory

Find out how the brain decides what to remember and what to forget

As you read this article, you store the words at the beginning of each sentence in your short-term memory while you work your way through to the end, enabling you to understand the text. At the same time, you are probably ignoring the feeling of the glossy pages against your skin as you hold the magazine.

Short-term memory acts somewhat like a gatekeeper between incoming sensory information and long-term storage. You are constantly bombarded by information, and the incoming traces from your sensory receptors last for just fractions of a second before they are lost. You don't have time to process all of it; so short-term memory allows you to pass small amounts of important information in a temporary loop while your brain decides what to do with it.

Short-term memory has two major limitations; the first is that you can only store a small amount of information, and the second is that the memory decays over time. If you pay attention, your short-term memory can hold around four chunks of new information for between ten and 20 seconds, but if you are distracted, you will rapidly forget it all.

Rehearsing the information inside your head effectively resets the timer and restarts the memory loop, allowing you to extend this time. A part of the brain called the hippocampus then decides which bits are important enough to be committed to longer-term storage, and the others are quickly forgotten.

Extending your short-term memory

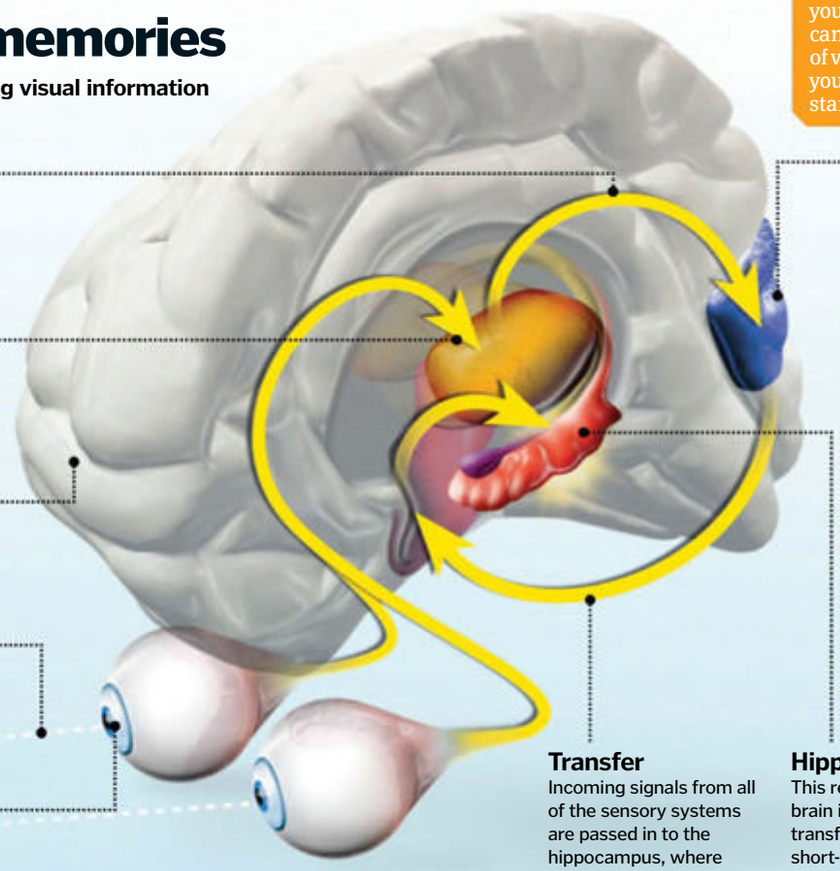
You can hold four items of information in your memory for around ten seconds without trying, but memorising a sheet of 20 words can prove challenging. Your short-term memory has its limitations, but you can improve it with a few simple tricks.

Instead of overloading your memory by trying to memorise them one by one, divide the images into linked chunks; for example, office objects or things that fly. This helps by tapping into your long-term memory, which mainly stores linked concepts, and is triggered by cues and associations.

Short-term memory tends to be encoded verbally, and you might find yourself repeating the names of the items in the pictures inside your head in order to help with recall, but you can improve still further if you take advantage of visual encoding. By creating a scene inside your head and visiting each item in turn, you start to remember the words more easily.

Making memories

Find out how incoming visual information becomes memory



Processing
The incoming signals from the eyes are passed to the occipital lobes for processing.

Thalamus
The thalamus is involved in attention and the early stages of short-term memory formation.

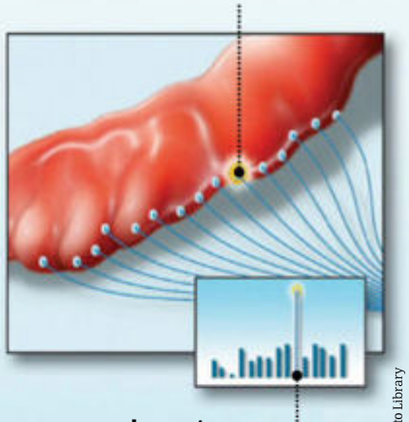
Prefrontal cortex
This part of the brain has a crucial role in coordinating short-term memory and in rehearsing information.

Attention
In order to transfer information from sensory memory to short-term memory you need to be paying active attention.

Input
Incoming information is stored for less than a second in your sensory memory.

Occipital lobe
The occipital lobes process incoming visual information.

Storage
Short-term memories are rapidly turned into long-term memories that can last days, weeks or even a lifetime.



Transfer
Incoming signals from all of the sensory systems are passed in to the hippocampus, where they are combined as a single 'experience'.

Hippocampus
This region of the brain is involved in transferring short-term memories into long-term storage.

Long-term memories
Memories are stored throughout the cortex as groups of nerve cells that fire together in coordinated patterns.

"This vast network of 100 million neurones constantly samples the ingested food, relaying this information to the brain"

How cravings work

Is a child destined to develop a taste for all things sweet?

Hunger and cravings are two very different things. While one is about survival, the other satisfies the nagging need for something sugary. It's believed we all develop a taste for sweetness in infancy. This stems from the predominant sweet taste of our mother's milk; when we taste it, the brain's reward centres light up, causing us to derive pleasure from this experience. As we continue to consume our mother's milk this pleasure is reinforced, which could explain how our sugar cravings originate.

Our mothers' diet can influence our preferences for certain foods. Scientists have found that flavours are transmitted from mother to baby via the amniotic fluid surrounding the foetus in the womb. Once born, the probability of the child disliking the flavours they have already experienced is reduced.

Our gut also plays a large role in cravings. The gut contains an almost separate autonomous system that governs the digestion lining. This vast network of 100 million neurones constantly samples the ingested food, relaying this information to the brain. This endless conversation can cause our appetite and cravings to change. The gut bacteria are also heavily involved; when they break down large quantities of fibre, they produce a specific compound that is sent to the brain, triggering it to feel full and satisfied from the recently ingested meal.

So should we consider cravings as a sign of food addiction? Although high-sugar and high-fat foods exhibit some of the hallmarks of addiction, the consensus is that it's actually the behaviour around eating these foods that we are addicted to.

People commonly crave the sweet taste and melt-in-the-mouth texture of chocolate

Learn more

The British Science Museum is currently running an exhibition on cravings. For more info, visit **www.sciencemuseum.org.uk**

Can the latest technology stop cravings?

There's a microchip that aims to control cravings, developed by Kings College London's Centre for Bio-Inspired Technology. Once implanted in the body, the chip will use electrodes to monitor the signals passing between the gut and the brain. By 'listening' to the communication between the two organs, the microchip will be able to recognise signals for cravings and alter these before they reach the brain.

Ghrelin is the body's hunger-inducing hormone. By using a ghrelin antagonist, scientists aim to suppress this hormone's activity, stopping cravings from ever materialising. This research has implications for the cravings of other substances too. Scientists have hypothesised that due to the similarities between this system and the system responsible for craving nicotine and alcohol, it may be possible to switch off these cravings as well as those related to food.

Tricking our senses

Does a spoon's colour change the way yoghurt tastes? In reality it doesn't, but the colour of cutlery can alter how you *think* something tastes. A recent study fed a group of volunteers the same yoghurt using a white and a black spoon. The results showed that the yoghurt was perceived to taste sweeter on the white spoon. Altering the spoon's weight was then tested. The lighter spoons caused the participants to feel the yoghurt was denser and more luxurious. Scientists are unsure what mechanism causes these bizarre results, and want to carry out further research into why we make these associations.

Plan your perfect day out

Inspire your family and go somewhere amazing this weekend. **GREAT DAYS OUT**, the new **FREE** iPhone app from **HOW IT WORKS**


NATIONAL PARKS


MUSEUMS

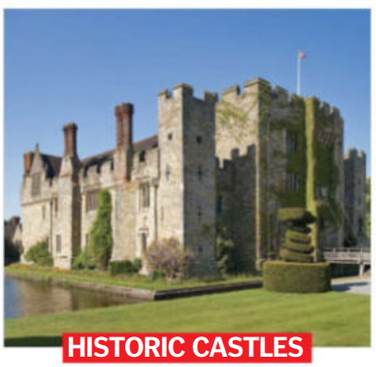

RAILWAYS


EXHIBITIONS & EVENTS


BEST BEACHES


ICONIC LANDMARKS


WILDLIFE PARKS


HISTORIC CASTLES

Search 'Great Days Out' in the App Store or visit **www.greatdaysoutapp.com**

Download on the App Store

"The traditional method of calorie calculation is to put the food inside a unit known as a bomb calorimeter"

How calories are calculated

A bomb calorimeter can tell us how much energy is in our food

Calories are a measure of energy and can be used to describe any fuel, from petrol to bread. One calorie is the amount of energy required to raise the temperature of one gram (0.035 ounces) of water by one degree Celsius (1.8 degrees Fahrenheit). Food labels often quote energy content in kilocalories (kcal), because food is so rich in energy that it makes more sense to label 1,000 calories at a time. This means a biscuit labelled as having '100 calories' actually has 100,000 calories, and can raise the temperature of one kilogram (0.45 pounds) of water from freezing to boiling point.

The number of calories in any given item of food is calculated by measuring how much energy is released when a substance is burnt. Inside our bodies, molecular machinery is responsible for burning the fuel we eat, but in the lab, using a spark gives the same result.

The traditional method of calorie calculation is to put the food inside a sealed unit known as a bomb calorimeter. The food is surrounded by an atmosphere of oxygen to ensure it will burn well, and the container is then sealed and surrounded by a known volume of water. A spark ignites the food inside and allows it to burn until it is reduced to charcoal, releasing all of the energy contained inside. The energy is converted to heat, which in turn raises the temperature of the water. By measuring the water's temperature change, you can then find out exactly how much energy has been released, and calculate the calories from there.

Today, many food manufacturers use a different system to create nutritional label; instead of burning the food item whole, they simply add up the calories of the different components, such as fats, carbohydrates and proteins.

Empty calories

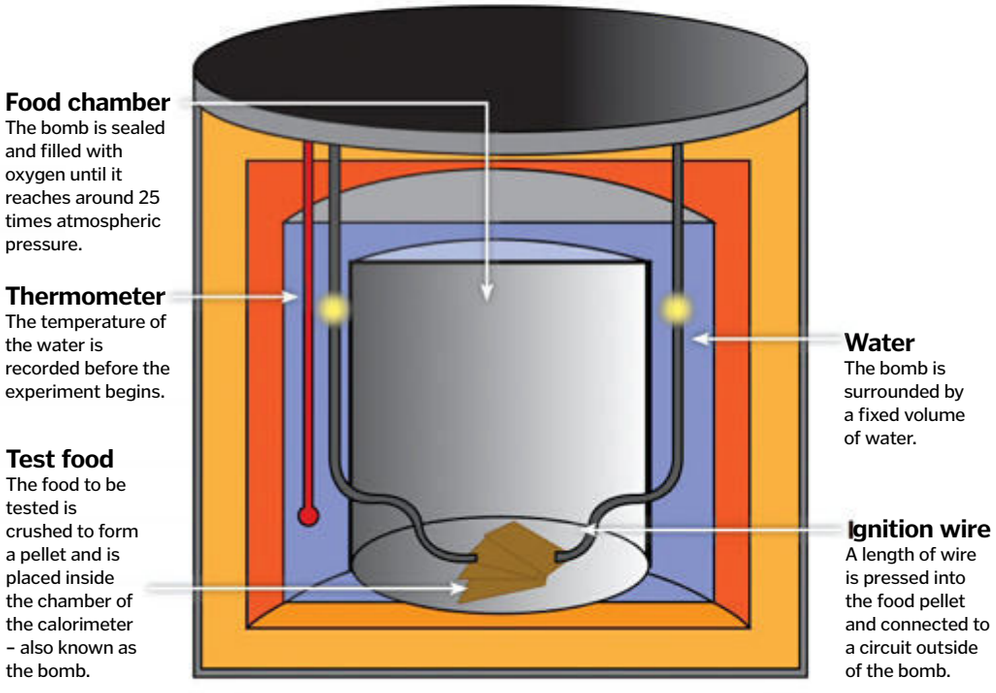
'Empty calories' is a term used by nutritionists to describe foods that have no nutritional value other than to provide energy, and the primary culprit is sugar. Added sugar adds calories and sweetness to our food, but in terms of nutritional value, there is no real benefit at all. As a species, we evolved to like the taste of naturally occurring sugars found in ripe fruits and berries, because these contained more calories than their unripe counterparts. These fruits also contain vital fibre, water and vitamins. Today we often add extra sugar to food for the taste alone, contributing a massive 15 kilocalories per teaspoon.

Calculating calories

Take a look inside a bomb calorimeter and find out how calories are calculated

1 Setting up the calorimeter

The first step in measuring the calorie content of our food is to place the item inside a bomb calorimeter. The food is sealed in a container filled with flammable oxygen gas, and is placed inside a second container containing a known quantity of water.



THE STATS
FAST FOOD CALORIES

508kcal MCDONALD'S BIG MAC

350kcal KFC HOT WINGS

NANDOS GRILLED PERI PERI CHICKEN BURGER 368kcal

190kcal KRISPY KREME GLAZED DONUT

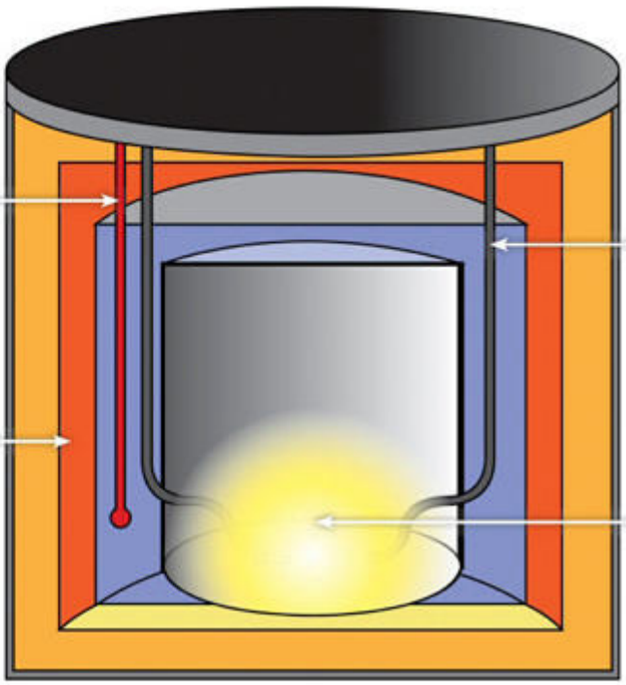
BURGER KING WHOPPER 650kcal

CINNABON CLASSIC 880kcal

DID YOU KNOW? *Calories don't just measure the energy content of food: one litre of petrol contains around 8 million kilocalories*

2 Burning the food

Food is fuel, and it is burnt inside our bodies using oxygen; the calorimeter simulates this in the lab. An ignition wire is used to set light to the food, and as it burns, the energy released is transferred into the water surrounding the chamber, causing the temperature to rise.



Temperature change
The water temperature begins to rise as the food releases its energy.

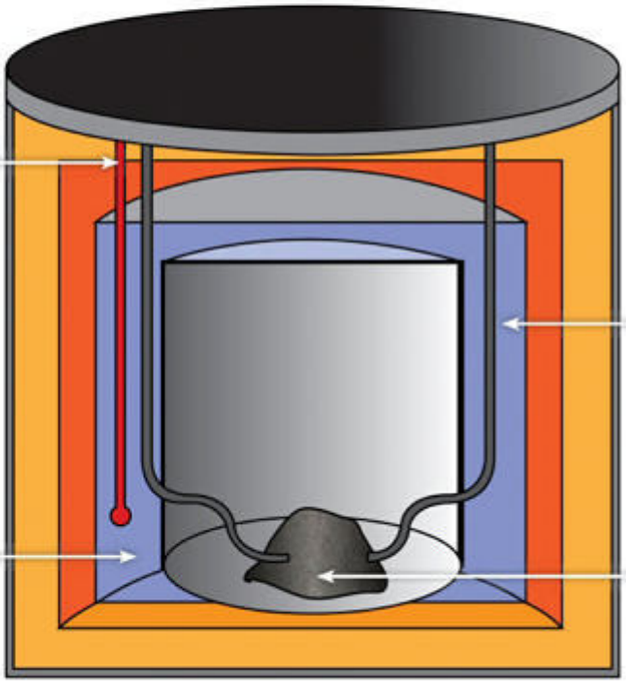
Insulation
Insulation and a vacuum gap around the water chamber prevent heat from escaping into the atmosphere.

Ignition
The food is ignited by passing a current through a wire inside the bomb.

Energy release
As the food burns, the energy released heats the water surrounding the bomb chamber.

3 Calculating the calories

When the food has been reduced to ashes, all of the energy stored inside has been released. The final temperature of the water is then taken and the difference between the start and end temperature is determined. This is multiplied by the number of grams of water that were contained within the calorimeter to give the total number of calories.



Final temperature
The temperature of the water is recorded, and compared against the original temperature.

Calorie content
The calorie content of the food is calculated using the change in water temperature.

Total calories
This food has raised 5kg (11lb) of water by 45°C (81°F), giving a total calorie content of 225kcal.

Ashes
The experiment ends when the food has completely burnt away.

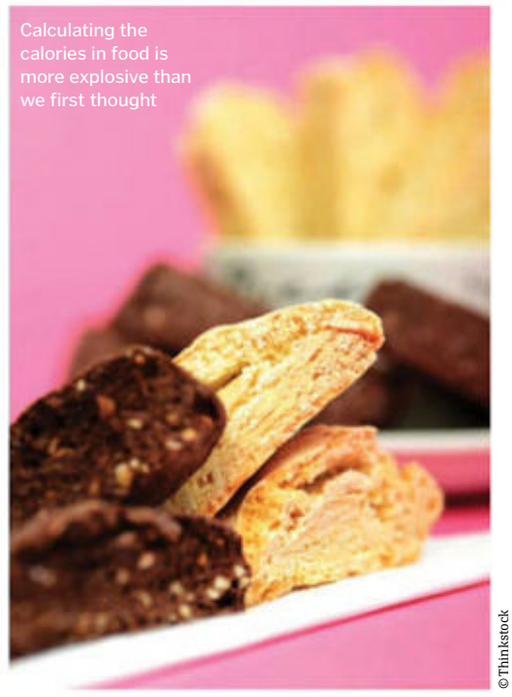
Calorie density

You might think you would feel full after a 200-kilocalorie snack, but your body knows when to stop eating not because you have taken in enough energy, but because stretch receptors in your stomach and chemical messengers sent to your brain signal that you are full.

Fat is the most calorie-dense type of food, containing around nine kilocalories per gram. Carbohydrate and protein contain around half the amount of kilocalories per gram, fibre containing around two kilocalories per gram, and water contains no calories at all.

For 200 kilocalories, you could have a small handful of salted nuts, half a blueberry muffin, a small bowl of cereal, three eggs, four apples, six slices of melon, or two entire heads of broccoli. By eating foods that contain lots of water and fibre, you can eat much larger quantities, and feel fuller, without taking in as many calories.

These foods all contain 200 kilocalories each



Calculating the calories in food is more explosive than we first thought

"A dry or tickly cough can erupt from the chest for a number of reasons"

How altitude sickness works

Discover the effect dizzying heights can have on the human body

Adventurous explorers can spend months training prior to scaling mountain peaks, but regardless of fitness level, high altitudes can take a toll on the human body.

Between around 1,524 and 3,505 metres (5,000 and 11,500 feet) above sea level is considered high altitude. Most travellers will start to feel the effects of high altitude sickness as they attempt to acclimatise to the change in atmosphere at these heights.

The most common symptom is shortness of breath, which is due to a lack of atmospheric pressure. At these heights, air molecules are more dispersed, so less oxygen can be inhaled. In order to compensate, your heart rate will increase and the body will produce more red blood cells, making it easier to transport oxygen around the body.

The low humidity levels at high altitude can also cause moisture in the skin and lungs to evaporate quicker, so dehydration is a real threat. Your face, legs and feet may start to swell as the body attempts to retain fluid by holding more water and sodium in the kidneys.

Difficulty sleeping is also common, and symptoms of high altitude sickness can get progressively worse the higher you climb, including mood changes, headaches, dizziness, nausea and loss of appetite.

High altitude sickness can have a severe physical effect on the human body. Descending to lower altitudes is the only way to ease symptoms

What is a dry cough?

Find out what triggers a dry cough and how it helps to keep your airways clear

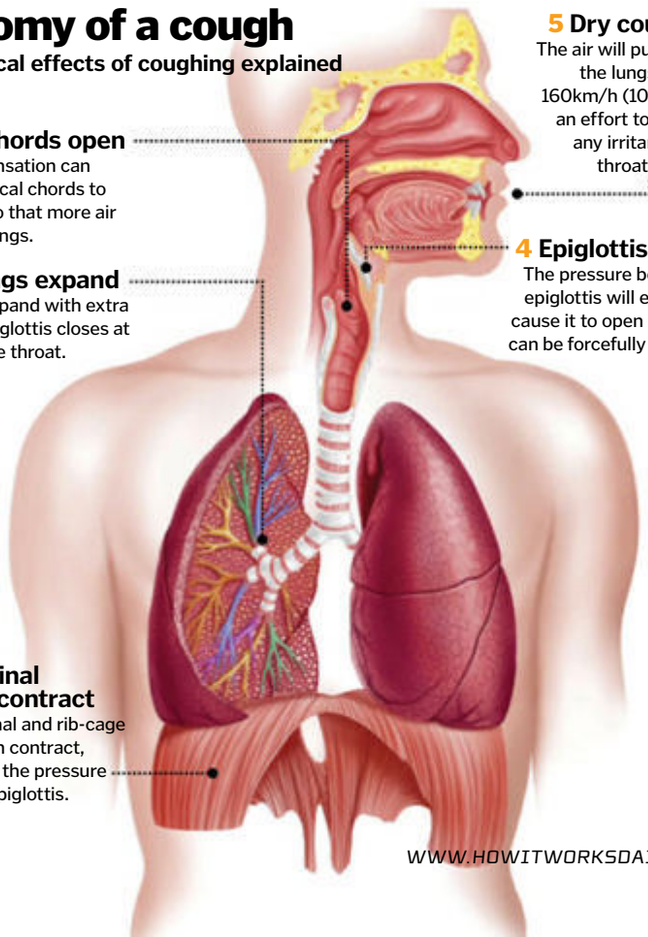
Coughing is an automatic defence reflex that helps to keep your airways and lungs clear. There are two different types; a productive wet cough, which produces mucus or phlegm, and a dry cough, considered nonproductive.

A dry or tickly cough can erupt from the chest for a number of reasons. It occurs when the throat and upper airways become inflamed, most commonly the result of an infection such as cold or flu, but it can also be triggered by irritants (such as dust, pollen or pet hair) or pollutants in the air. The body assumes this inflammation is a foreign object partially blocking the airway and initiates the cough reflex in order to remove it.

The vocal chords within the trachea open wide to allow more air into the lungs. The epiglottis at the top of the throat will then close off the windpipe while the abdominal and rib muscles contract. This increases the pressure behind the epiglottis, which opens to expel the air at up to 160 kilometres (100 miles) per hour.

Anatomy of a cough

The physical effects of coughing explained



1 Vocal chords open
A tickling sensation can cause the vocal chords to open wide so that more air enters the lungs.

2 The lungs expand
The lungs expand with extra air as the epiglottis closes at the top of the throat.

3 Abdominal muscles contract
The abdominal and rib-cage muscles then contract, which builds the pressure behind the epiglottis.

4 Epiglottis opens
The pressure behind the epiglottis will eventually cause it to open so the air can be forcefully expelled.

5 Dry coughing
The air will push out of the lungs at up to 160km/h (100mph) in an effort to dislodge any irritants in the throat or lungs.

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ALWAYS LEARNING

PEARSON

Air traffic control

We visit the control centre responsible for keeping the UK's skies safe

Over 6,000 flights travel into, out of and through UK airspace every day. That's more than 2 million flights every year carrying over 220 million passengers to destinations all over the world. To find out how this staggering amount of traffic is managed, **How It Works** went to visit the NATS control centre at Swanwick in Hampshire, England.

NATS provides navigation services to all aircraft flying in UK-controlled airspace and over the eastern part of the Atlantic. When you think of air traffic control, you probably think of big control towers at airports, but the majority of the work is actually done at the two NATS control centres at Swanwick and Prestwick in Ayrshire, Scotland.

Before each flight, an airline will file a flight plan, which is then evaluated by NATS. The aircraft's fuelling needs, traffic patterns and weather conditions are all considered to ensure a safe and efficient route. Controllers in the airport towers are then responsible for clearing the aircraft for takeoff and coordinating its movements on the ground, but once your flight is airborne, it is then handed over to the air traffic controllers at Swanwick or Prestwick, depending on its route.

Controllers at Prestwick handle aircraft in the airspace over Northern England, Scotland, Northern Ireland and the Eastern Atlantic. At Swanwick, controllers in the London Terminal Control Centre (LTCC) handle traffic taking off and landing in Southern England, while controllers in the London Area Control Centre (LACC) manage all traffic in the airspace over England and Wales.

Controlled airspace is made up of a network of corridors called airways, which are a bit like roads. Each one is 16 kilometres (ten miles) wide and 1,524 metres (5,000 feet) high and they crisscross through the skies between the UK's major airports. In these airways, all aircraft must be separated by at least 9.26 kilometres (5.75 miles) horizontally and 305 metres (1,000 feet) vertically. However, in lower airspace, just before takeoff or landing, the horizontal distance is reduced to 5.56 kilometres (3.45 miles) as the aircraft are travelling slower.

In uncontrolled airspace, pilots are responsible for their own safety, but they can receive help from military controllers, also known as 'blue shirts', on the control-room floor. They are in charge of search-and-rescue operations for aircraft in distress and also help deal with 'infringers', aircraft that enter controlled airspace without permission.

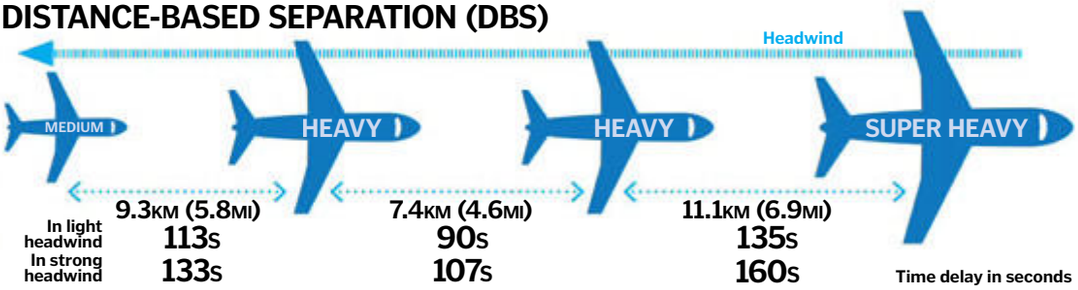
DID YOU KNOW? *Aircraft carrying royalty are given special 'purple flight' status, meaning they get extra space in the air*

Aircraft separation

As aircraft make their final approach into an airport, they are separated by distance, and this distance varies depending on their size. All aircraft create a vortex – spirals of air trailing from the wingtips – in their wake. This wake vortex creates an area of turbulence that can destabilise any aircraft that flies into it, and so must be left clear at all times. The larger the aircraft, the more turbulence it creates, and so the greater the distance between it and the following aircraft needs to be. For example, 11 to 13 kilometres (6.8 to eight miles) of space needs to be left behind a larger Airbus A380, but a smaller Boeing 737 only needs about 5.6 kilometres (3.5 miles). The distance also depends on the size of the aircraft following, as the larger the plane, the less effect the turbulence created by the aircraft in front will have on it. Therefore, a large aircraft can follow a smaller one quite closely, but a small aircraft will need to keep a big distance behind a larger one.

The problem with the distance based separation (DBS) system is that, when flying into strong headwinds, the ground speed of the aircraft is reduced, causing it to take longer to fly this required separation distance. Therefore, strong headwinds significantly lower the landing rate and these are the biggest single cause of landing delays at Heathrow Airport.

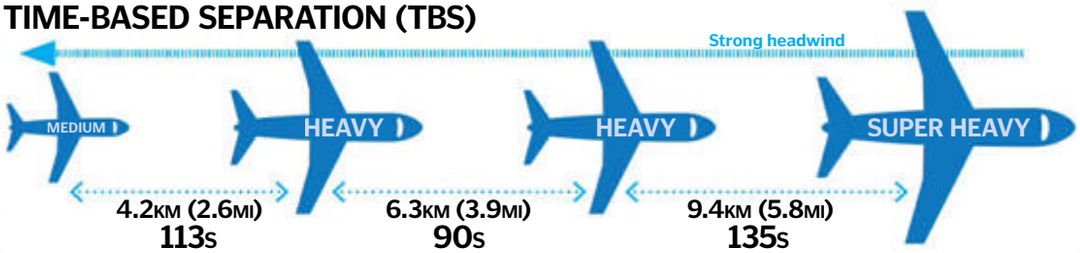
DISTANCE-BASED SEPARATION (DBS)



To solve this problem, NATS has developed a new system that separates the aircraft based on time instead of distance.

It discovered that when flying into strong headwinds, an aircraft's wake vortex dissipates more quickly, meaning the distance between them can be reduced. Using real-time wind data, the optimum distance between aircraft is calculated for the specific conditions, helping the controller maintain a normal landing rate of about 40 aircraft per hour. This new system is being introduced at London Heathrow Airport in spring 2015, with the hope that it will significantly reduce the number of flight delays and cancellations.

TIME-BASED SEPARATION (TBS)



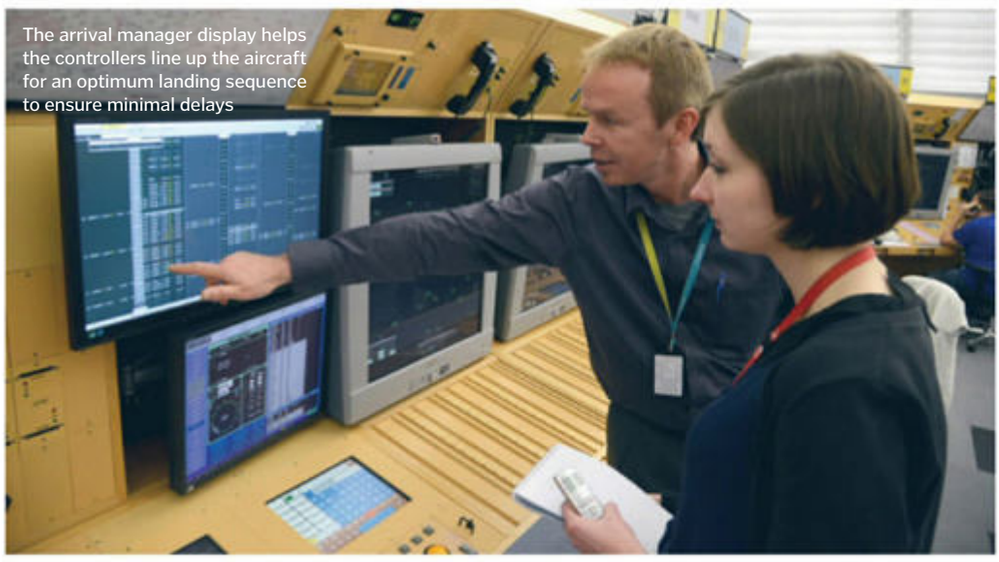
Drones in the airspace

One of the latest must-have gadgets on any tech fan's wish list is a drone. As they've become cheaper, smaller and easier to fly in recent years, these remote-controlled flying machines have risen in popularity. However, despite being relatively small, drones can pose a threat to other aircraft, particularly if they fly into its engines, and so some strict restriction are in place to dictate where you can fly one. Andy Rolfe, head of safety assurance at London Terminal Control, Swanwick Control Centre, says: "The Civil Aviation Authority is thinking more about how it regulates drones and it has already come up with some regulations. For example, you shouldn't be flying a drone into controlled airspace without clearance from air traffic control," he continues. "However, you can still fly a drone underneath that airspace. When it comes to flying drones in uncontrolled airspace, they still need to think about how to stop them banging into each other or into other small aircraft. We have had pilots report sightings of drones so it's definitely an increasing problem."

Most drones are too small to be detected using traditional air traffic surveillance systems, such as radar

Looking around the Swanwick control centre, we were struck by how human-led it is. Although ground-based radar systems and satellite links are used to keep track of all aircraft, it is still down to the controllers themselves to organise flights in the air and give direct instructions to the pilots. Andy Rolfe, head of safety assurance at London Terminal Control, Swanwick Control Centre says: "We're a very safety-orientated business, but if you compared us to, say, the nuclear industry, which is also very safety orientated, there's a big difference in our operations. A nuclear power station could almost run without humans, while our operation is very human-centred."

The controllers do get some help from technology. One of the most important systems used is the interim Future Area Control Tool Support (iFacts). This gives the controllers a



The arrival manager display helps the controllers line up the aircraft for an optimum landing sequence to ensure minimal delays

"Each controller can manage up to ten aircraft at a time in peak demand"

15-minute look into the future, alerting them if two planes are going to come within the required separation distance from each other, allowing them enough time to instruct the pilots to change course. An automated arrival manager system can calculate an optimal landing sequence for aircraft, but a controller is still needed to monitor and tweak this to make sure it is as safe and efficient as possible, and redirect aircraft if long delays are likely to cause them to run out of fuel.

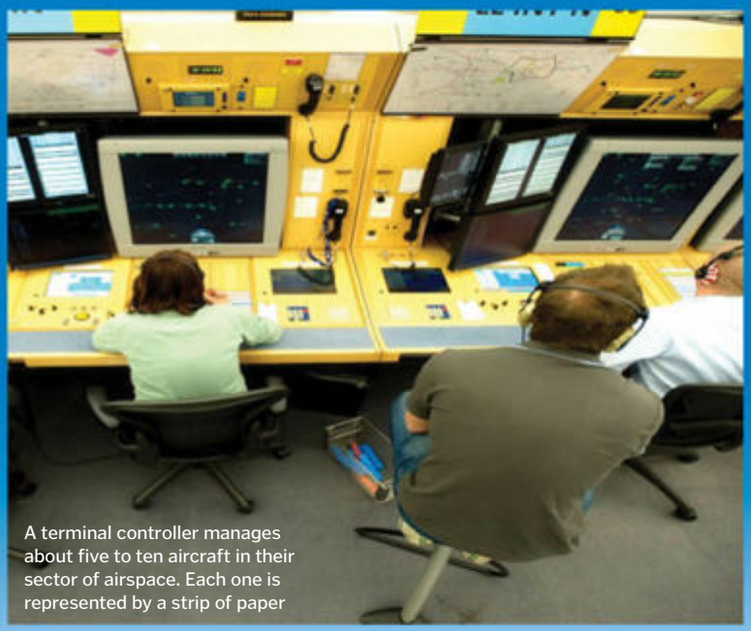
The LACC looked just as we expected, with rows of sleek and modern computers. However, we were surprised to see the technology in the LTCC looks much more old-fashioned, with chunky telephone handsets and big computer monitors. Andy says: "All of the kit is actually less than ten years old, but when it was moved from where it used to be near Heathrow, it was all kept pretty much the same to make the transfer smoother for the controllers."

The job of a controller seems complicated to our untrained eyes, with lots of baffling radar screens and other displays to keep track of, but each person can manage up to ten aircraft at a time in peak demand. UK airspace is divided into several different sectors, and each one is represented by a different station in the control room. The controller at that station is in charge of all of the aircraft in that sector, but when they pass into the next sector, they then hand them over to the next controller in charge, whether they are in the same control room, or in another country. It's basically like a big relay race and the aircraft is the baton. In fact, a typical flight from London, Heathrow to JFK in New York can be passed between 16 different controllers across the world.

A relay race in the skies

Your flight is passed between several different air traffic controllers as it travels from A to B

Controllers in the airport control tower manage the initial takeoff and final landing



A terminal controller manages about five to ten aircraft in their sector of airspace. Each one is represented by a strip of paper

Taking off

Once all of the passengers are on the aircraft and it is ready to go, the pilot contacts the delivery controller in the airport control tower. They will give the pilot air traffic control clearance, before passing them on to the ground movement controller, located elsewhere in the tower. It's their job to tell the pilot when they can push back and taxi toward the runway. They are then transferred to the tower's air controller, who lines up the aircraft on the runway and provides final clearance for take-off. When the aircraft is above 914 metres (3,000 feet), the air controller in the tower hands the pilot over to a terminal controller at the LTCC.

Ascending

The flight details of the aircraft are printed onto a strip of paper and handed to the terminal controller in charge of outbound flights for that airport. That controller then checks in with the pilot via radio link and guides them though their sector of airspace before passing the aircraft, and its strip of paper, to the next sector's controller. A pilot has to speak to many different controllers throughout a flight, and it's the job of each controller to tell them which radio frequency to switch to when they hand them over. LTCC helps the aircraft navigate London's busy airspace until it reaches 7,467 metres (24,500 feet).

94.4 MILLION

WORLD'S BUSIEST AIRPORT

Hartsfield-Jackson Atlanta International (ATL) in Atlanta, USA, is the world's busiest airport with 94.4 million passengers flying in and out during 2013. It has taken the title every year since 2000.

DID YOU KNOW? *During the London 2012 Olympic Games, the airspace over the city had to be reorganised to cope with the demand*

The life of an air traffic controller

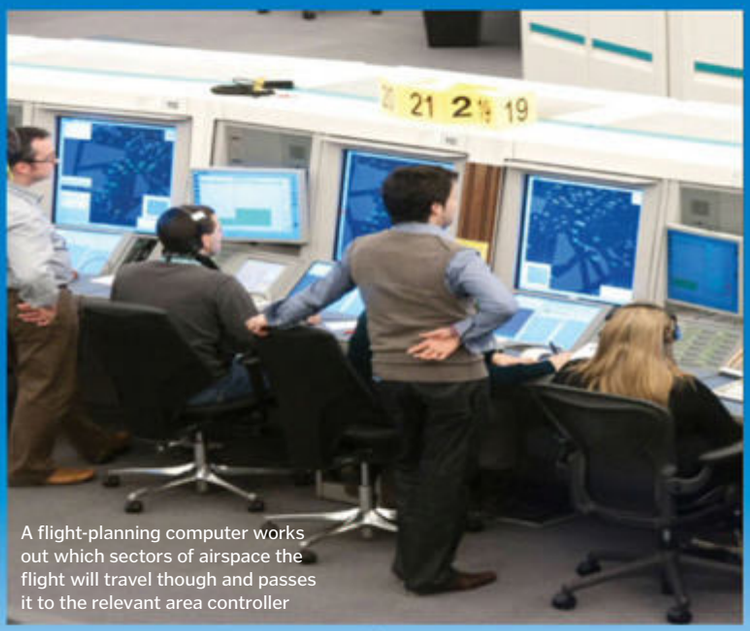
To become a NATS controller you must be aged between 18 and 65 and have a minimum of five GCSE qualifications. However, being a successful controller isn't so much about your background as it is about how you approach problems, handle pressure and adapt to changing situations. If you pass a series of assessments and interviews, you must then complete three years of training before becoming validated.

The job of a controller is very demanding and is therefore heavily regulated. They cannot work for more than an hour and half without a break and their shifts are split across the week so that they have plenty of days off for rest. The control rooms have a quiet and calm atmosphere and the layout, lighting and heating are all carefully monitored to make sure the controllers are as comfortable as possible with minimal distractions. An on-site aeromedical centre also monitors the health and wellbeing of the controllers, making sure they are fit to carry out their responsibilities.

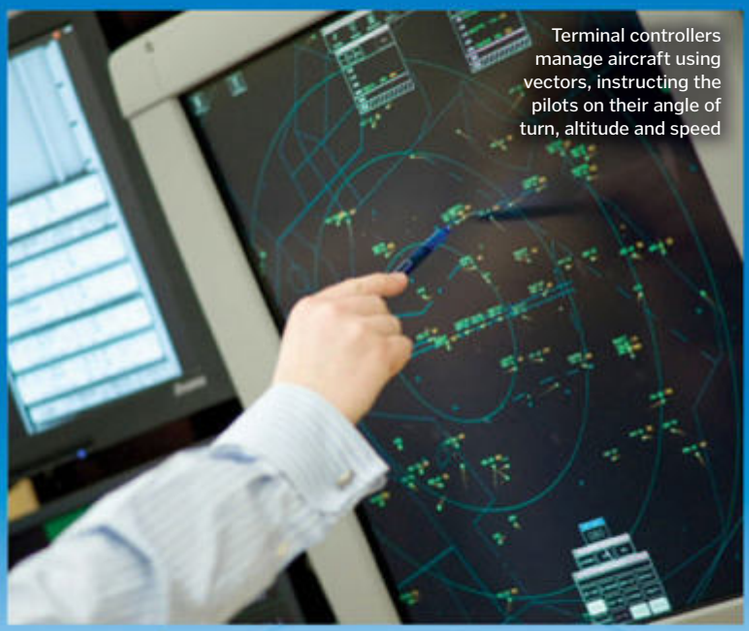
As the job is so demanding, air traffic controllers are also well paid and can earn up to £100,000 ($150,500) a year

Learn more

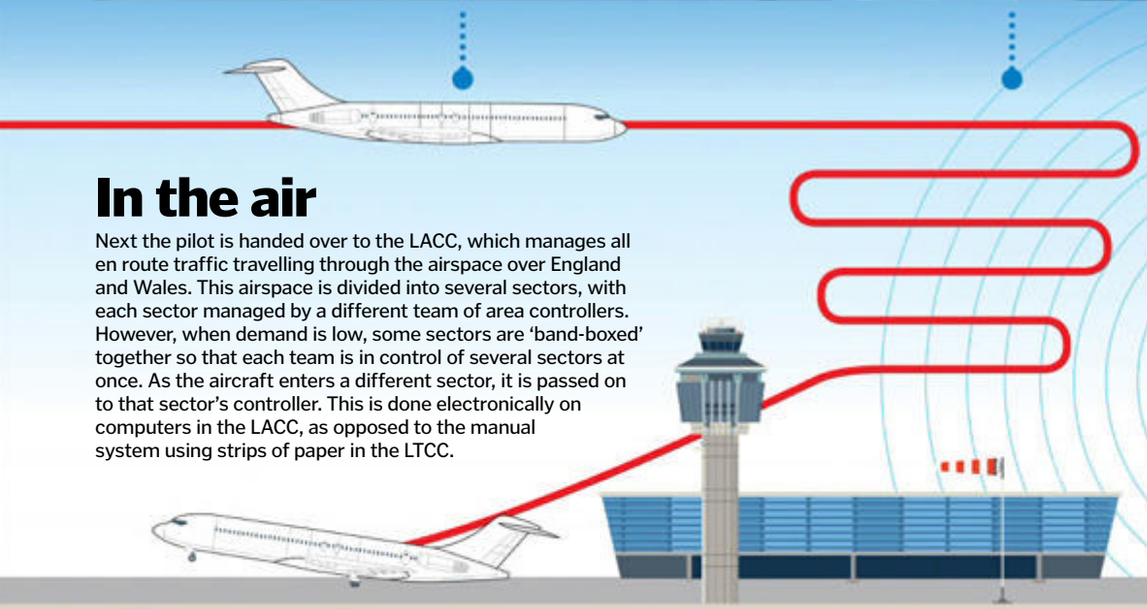
Do you think you have what it takes to become an air traffic controller? Visit **www.nats.aero/careers/trainee-air-traffic-controllers/games** to test your shape tracking, sequential memory and reactive avoidance skills with a series of online games.



A flight-planning computer works out which sectors of airspace the flight will travel though and passes it to the relevant area controller



Terminal controllers manage aircraft using vectors, instructing the pilots on their angle of turn, altitude and speed



In the air

Next the pilot is handed over to the LACC, which manages all en route traffic travelling through the airspace over England and Wales. This airspace is divided into several sectors, with each sector managed by a different team of area controllers. However, when demand is low, some sectors are 'band-boxed' together so that each team is in control of several sectors at once. As the aircraft enters a different sector, it is passed on to that sector's controller. This is done electronically on computers in the LACC, as opposed to the manual system using strips of paper in the LTCC.

Landing

When the aircraft is preparing to land, it descends to below 7,467 metres (24,500 feet) and is handed back to the LTCC. When an aircraft approaches a major airport, it often circles overhead in a so-called holding stack. Each stack is managed by a terminal controller, who then delivers the flights in that stack to another terminal controller using the paper-strip system. They line up the aircraft so that they approach the runway a safe distance apart. Once they are correctly separated, the aircraft are handed back to a controller in the airport tower, who guides them in to land.

"The driverless RS7's racing line was nearly identical to that of a seasoned racing driver"

Driver versus driverless

How the Audi RS7 driverless car can set a faster lap time on its own than with a human at the wheel

It's the age-old debate: is technology better than the talents of humans? In the automotive world, this argument is fast rearing to a head, with driverless cars now being fully tested on public roads around the world. However, while driverless cars are primarily aiming to be safer than those piloted by a human being, German manufacturer Audi wanted to find out if they are faster, too. The answer to this is the Audi RS7 driverless car prototype, a pumped-up sports car that's been specially adapted with driverless technology.

The RS7 driverless concept works in much the same way as a conventional driverless car currently being developed by other manufacturers, including Toyota and Google. As well as an advanced GPS system with pinpoint accuracy, cameras are placed around the vehicle that 'read' signs and the layout of the road or track ahead. These work in tandem with sensors and radars dotted around the vehicle, which constantly monitor the proximity of the car to the road and other objects. All this information is fed to a central computer, which processes the information and operates the car accordingly.

Where the Audi RS7 triumphs over other driverless cars, though, is not only in the speediness of this entire process, but also in its intelligence. On a track, a 'racing line' is taken by drivers to get around the track in the quickest time. This involves using the entire width of the track, braking at the last possible moment before a corner, and keeping the car perfectly balanced throughout. As a thrash around the Hockenheim circuit demonstrated, the driverless RS7 prototype was found to take a very precise racing line on the track, nearly identical to that of a seasoned racing driver. The technology isn't without merit, either: a driverless RS7 actually beat a lap time around the Ascari circuit (by two whole seconds!) set by a human being in an identical car.

The driverless Audi RS7 in action

Here's how the driverless Audi RS7 prototype races round a track without any human input

The evolution of the driverless car

The driverless car industry is fast evolving within the automotive industry. Interestingly, it's not car manufacturers themselves that are at the forefront of the technology either: that accolade goes to technology giant Google, which has developed a unique pod-like vehicle that contains a single cushioned bench inside for all occupants to sit on. Materials used on the Google car are also ground-breaking, with a bendy facia and plastic windscreen implemented to help cushion the blow to a human in the unlikely event of a collision.

Other companies such as Toyota or Volvo have been busy adapting their own conventional passenger vehicles to accommodate driverless tech, but the roof-mounted radar and bigger computers have often proved unsightly and impractical. But there's more: rumours are also gathering pace that Apple is developing its own autonomous vehicle, so watch this space...

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

See the Audi RS7 racing around a track by itself!

www.howitworksdaily.com

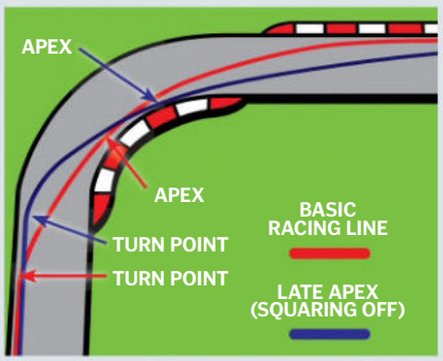
DID YOU KNOW? *In 2010, a driverless Audi TTS successfully took on the Pikes Peak hillclimb challenge*

Car controls
The ECU sends inputs to the car's controls, such as steering or throttle input.

Infrared camera
An infrared camera is fitted to enable the car to be driven in darkness thanks to night vision.

Central ECU
This constantly processes all the data from cameras, sensors and GPS, and decides how to control the car as a result.

Ultrasonic sensors
Dotted all around the car, these constantly monitor the proximity of the car to the edge of the track.



Racing line: the quickest way around the track

Race drivers will take a certain line around a race track, in order to complete a lap in the shortest time possible. This is called a 'racing line' and is best described as a route that cuts through corners – without cheating, of course – most effectively, and enables the driver to keep their foot on the accelerator pedal for the longest possible time. Different racing drivers will interpret different racing lines on a track – there is no right or wrong here – though drivers in a world-class competition like Formula One will likely take very similar lines after years of experience and practice on each circuit.

Audi's RS7 driverless concept could be bad news for professional racing drivers in the long term

"These warning lights are built into an otherwise ordinary-looking helmet, which pulse from its beak"

Smart helmet: predicting accidents

This new helmet for cyclists helps to prevent collisions

Cyclists have long worn helmets to protect their head in the event of a collision. Now though, Swedish automotive manufacturer Volvo has created a pioneering new smart helmet that not only protects the cyclist, but also warns them of potential accidents. The helmet is part of a two-way system where both cyclists and drivers continuously upload their location to a cloud system. The system can then warn the respective parties as to the proximity or direction of oncoming objects that interferes with their own location and trajectory.

For cars, these warnings are conveyed via warning lights on a heads-up display system in front of the driver on their windshield, which is particularly useful for when a cyclist is in a vehicle's blind spot. For cyclists, these warning lights are built into an otherwise ordinary-looking helmet, which pulse from its beak. This ensures the cyclist is alerted to the impeding danger with enough time to take evasive action, without the lights becoming overbearing or impairing the vision of the cyclist.

While this is a great idea in principle, there are limitations to this early stage of technology. First, not everybody drives a Volvo, and second, many people will feel uncomfortable uploading their current location to a cloud sharing service.

Safety in action

How Volvo's new smart helmet detects accidents waiting to happen

Smart helmet
This looks like a conventional helmet, but it has Bluetooth connectivity to a smartphone app and tiny lights affixed to its front.

Warning lights
When the system recognises another vehicle is about to interrupt the trajectory of the cyclist, red lights flash to warn the cyclist of impending danger.

Smartphone
The cyclist registers to the cloud via a smartphone app, which also links to the smart helmet to purvey messages of potential danger in the vicinity.

Cloud system
This is a central database that constantly logs and maps the location of all its users, which is key to the safety system.

Automobiles
Cars also log on to the cloud system in order to communicate their location and proximity to cyclists.

The science of solar panel parking

This regenerative energy source recharges electric cars without a plug in sight

Electric and hybrid cars are becoming much more of a common sight on the roads, with many plug-in charging stations now visible in car parks and service stations around the globe. However, there's a new technology now available that enables these cars to be charged without the need for a mains power supply, instead drawing on energy from the Sun.

This system of solar panel parking works by converting daylight energy into electric energy, trickle-charging cars ready for use. Photovoltaic panels mounted to the roof of the parking lot or carport absorb the Sun's rays and convert the solar energy into electric energy compatible with the automobile, which is fed in via an adaptor to the car's standard electric charging port.

However, while this can reduce costs of electricity charging at the mains, photovoltaic panels are not yet efficient enough to convert all the solar energy they receive into electricity, so several hours of solar charge won't power a car for a long period of time. The technology is in its infancy, though, and could well provide a framework for the future of regenerative-fuelled motoring.

This solar panel parking unit was installed at a parking lot in Portland, USA, in 2011 for electric cars to use

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Visit our website to see the AirBoard in action

www.howitworksdaily.com

DID YOU KNOW? *A popular use for the AirBoard is cattle herding as it is a cheaper and safer option than horseback or helicopter*

The AirBoard

Meet the smallest one-person aircraft in the world

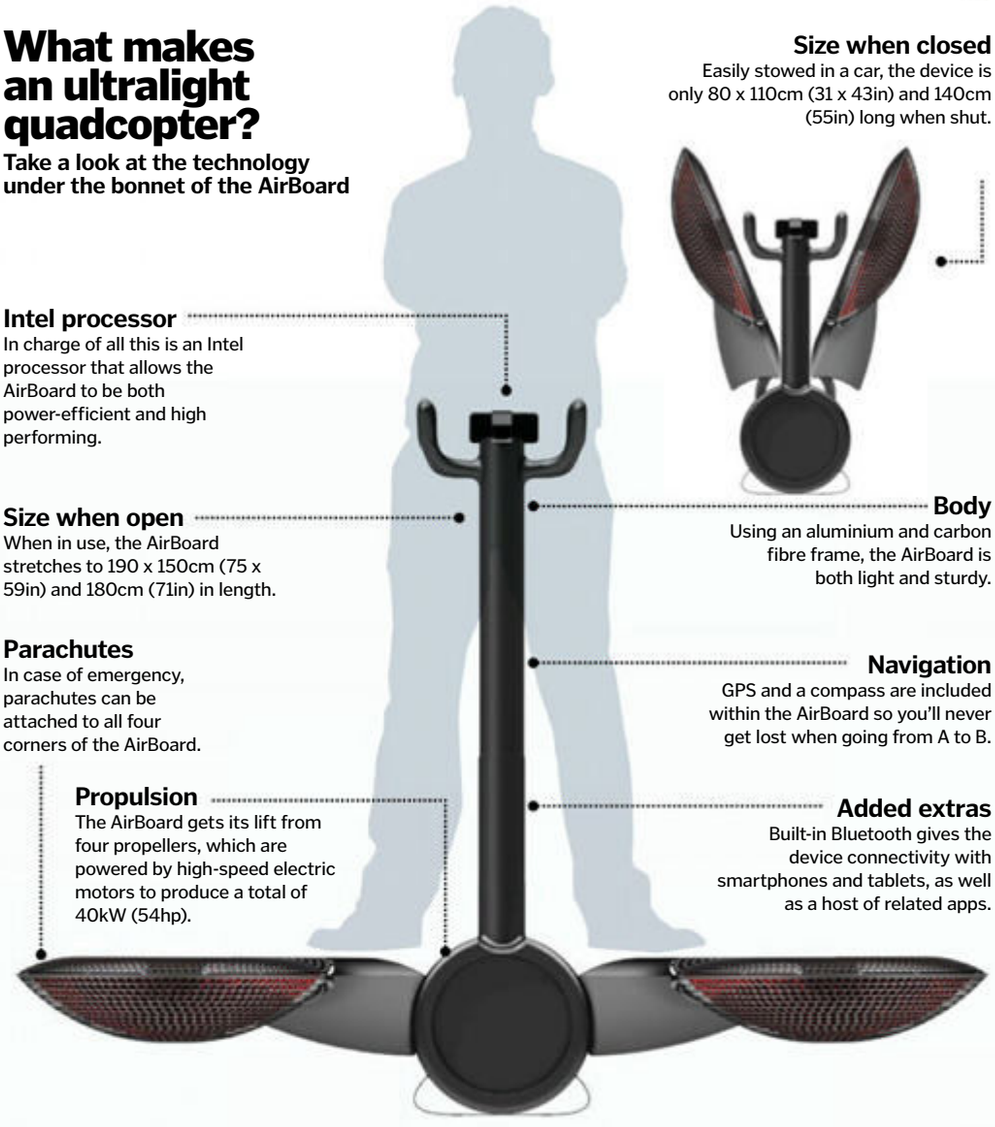
Ever wanted to fly but don't have the time or money to train as a pilot? The new AirBoard could be the answer. The smallest one-person aircraft in the world, it can carry the weight of a single person using its powerful battery. The AirBoard is classified as an ultralight quadcopter aircraft and it's small enough to fit in the boot of your car.

Its thrust is provided by four high-speed electric motors that each power a propeller. The drive system is managed by an Intel processor chip that incorporates a ground collision sensor to keep the board at a set height above the ground. This system comes into its own when you take the AirBoard into the great outdoors. Designed for both urban and rural use, the quadcopter will hover over nearly all ground, whether it's a snowy plain, water, rocky terrain or just in the street.

The device is easy to control, requiring the user to merely lean in the direction they want to go. For safety, the board's altitude is limited to a tame 1.5 metres (4.9 feet). The AirBoard's qualities make it ideal for recreational use but its features also make it potentially useful in search and rescue for the emergency services and perhaps even espionage for the military.

What makes an ultralight quadcopter?

Take a look at the technology under the bonnet of the AirBoard



Size when closed
Easily stowed in a car, the device is only 80 x 110cm (31 x 43in) and 140cm (55in) long when shut.

Intel processor
In charge of all this is an Intel processor that allows the AirBoard to be both power-efficient and high performing.

Size when open
When in use, the AirBoard stretches to 190 x 150cm (75 x 59in) and 180cm (71in) in length.

Parachutes
In case of emergency, parachutes can be attached to all four corners of the AirBoard.

Propulsion
The AirBoard gets its lift from four propellers, which are powered by high-speed electric motors to produce a total of 40kW (54hp).

Body
Using an aluminium and carbon fibre frame, the AirBoard is both light and sturdy.

Navigation
GPS and a compass are included within the AirBoard so you'll never get lost when going from A to B.

Added extras
Built-in Bluetooth gives the device connectivity with smartphones and tablets, as well as a host of related apps.

The contenders

More tiny aircraft proving that bigger isn't always better

Messerschmitt Me-328

It may have never made it past the prototype stage, but the Messerschmitt Me-328 is the smallest pulsejet fighter of all time. It would have been used by Nazi Germany as a parasite fighter launched off larger aircraft.

Bumble Bee II

The tiny 2.7m (8.8ft)-long Bumble Bee II is listed by the *Guinness Book Of Records* as the smallest aircraft ever made, but it was sadly destroyed in a crash in 1988.

Bede Bd-5

The Bede BD-5 is considered the smallest civilian jet but not the world's smallest aircraft. Its first flight was in 1971 and despite its 3.8m (12.5ft) length it can reach a top speed of 483km/h (300mph).

XF-85

A prototype parasite fighter like the Me-328, the American XF-85 Goblin was the world's smallest jet fighter. At 2,050kg (4,519lb) when loaded, it is significantly heavier than the civilian aircraft on the list, mainly due to its four machine guns.

SAVE RHINOS NOW

10% OF OUR PROFITS HELP FIGHT POACHING

An animal in crisis
In eastern Africa, poachers use automatic weapons to slaughter endangered rhinos. The animals are shot and the horns are hacked away, tearing deep into the rhinos' flesh with the rhino left to die.

Make a difference today
Ol Pejeta is a leading conservancy fighting against this cruelty. It needs more funds so more rangers and surveillance can be deployed on the ground to save rhinos from this horrible treatment.

Join World of Animals
World of Animals magazine takes a stand against these atrocities and is proud to be in partnership with the Ol Pejeta Conservancy – 10% of our profits go towards saving rhinos in the fight against poaching

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DID YOU KNOW? According to UK law, the front windscreen must let at least 75 per cent of light through

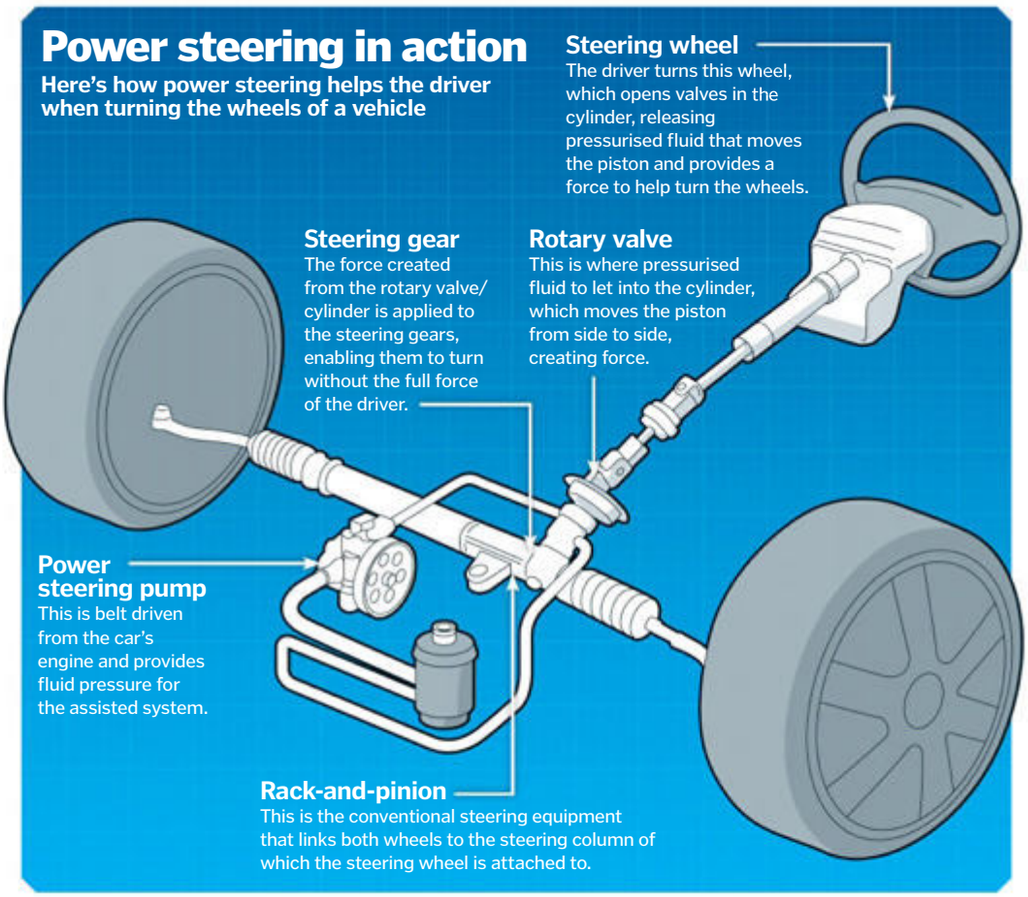
Power steering explained

This clever system provides extra power when turning the wheel

Believe it or not, the steering system on a car is very heavy. Think about it: when the driver turns the steering wheel, they are shifting the direction of two wheels, tyres, brake discs and pads, plus all the metal framework attached between the steering wheel and the driven wheels outside. For the last 30 years, most cars have deployed a system to assist the driver by providing extra power when turning the wheel. This is called power-assisted steering.

It works through a hydraulic system, where a pump, running off a belt from the engine, creates hydraulic fluid pressure. This fluid pressure moves a piston inside a cylinder, which applies force to the gears on the rack-and-pinion steering system. When the driver turns the steering wheel, this opens valves in the cylinder, letting fluid pass into it, moving the piston and creating added force.

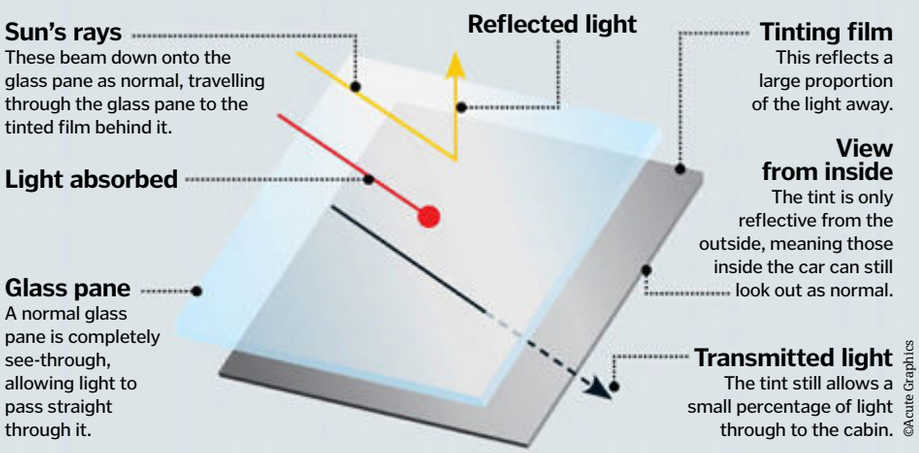
However, hydraulic-assisted steering creates extra drag on the engine due to that pump, meaning engine efficiency (and therefore MPG) is reduced. To combat this, manufacturers have now developed electric power-assisted steering (EPAS). This works by an electric motor mounted on the steering rack forcing the steering round, working independently of the engine, thus improving fuel economy.



The physics behind tinted windows

How a basic film protects occupants of a car from the Sun's powerful rays

You may see them being used on executive cars and limousines as 'privacy glass', but the original purpose of a tinted car window is to block the Sun's rays from entering the vehicle, keeping the occupants inside cool while still enabling them to see outside. Tinted glass works by applying a thin film tint to a pane of glass. The tint is sticky, so careful application is essential to avoid creating air bubbles between the glass pane and tint. The tint simply reflects the sunlight, meaning only a small percentage of the Sun's rays are transmitted into the vehicle. The heavier tint you have, the less the Sun's rays are transmitted into the vehicle – but be careful, as this is to the detriment of vision through the window.



Life on the coral reef

Explore the rainforest of the seas and the creatures that call it home

Coral reefs are one of the most diverse ecosystems on the planet, and thousands of sea creatures call it home, from microscopic organisms to enormous predators. In fact, the coral is an entire colony of living animals in itself, because unlike plants, corals do not make their own food. They spread across the ocean floor and provide shelter and food for the reef's other residents. Tiny plantlike organisms called phytoplankton sit at the bottom of the reef food chain, getting their energy from the sunlight that penetrates the shallow water. They serve as food for larger zooplankton, which are in turn eaten by corals, sponges, sea urchins and a whole host of other creatures. Several species of fish, mollusc and crustacean then take advantage of this buffet, before they become lunch for the sharks, rays and the marine mammals at the top of the chain. Each creature plays an important role in this delicate ecosystem, which requires a specific set of characteristics to survive.

Anatomy of coral

Coral is in fact a colony of hundreds or thousands of animals called polyps

Size
Most polyps range from 1-3mm (0.04-0.1in) in diameter, but some corals have single polyps that can grow to up to 25cm (10in) in diameter.

Stomach
The stomach at the centre of each polyp has a single opening that is used to ingest food and excrete waste.

Tentacles
Tentacles, typically in sets of six, are used for defence and to capture and pass food into the mouth.

Shallow reefs
Reefs typically grow best at depths of 18-27m (60-90ft), shallow enough for sunlight to reach the coral for photosynthesis.

Stinging cells
Nematocysts fire from each tentacle, injecting poison into the coral's prey to immobilise or kill them.

Reproduction
Polyps can reproduce both sexually and asexually in their lifetime, helping them to increase diversity and spread further.

Tissue layer
The coral skeleton is covered with a layer of tissue that allows the polyps to distribute nutrients between them.

Photosynthesis
Zooxanthellae algae lives in the coral's tissue, trapping sunlight to provide energy and receiving carbon dioxide and nitrogen from the polyps in return.

Deep-sea coral
Some coral reefs can be found at depths up to 6,000m (20,000ft) but all their energy comes from consuming prey instead of photosynthesis.

Growth
Polyps initially attach to rocks and other debris. Eventually, new polyps grow on dead polyp skeletons to build up as coral.

Skeleton
Hard coral polyps secrete calcium carbonate from their base, forming a protective skeleton that connects them together.

Protection
Coral polyps can retract their tentacles into their hard skeleton for protection if a predator approaches.

25% of all marine life can be found in coral reefs

5 TOP FACTS THE GREAT BARRIER REEF

Really great
1 The world's largest coral reef is about 2,300km (1,429mi) long. It's about half the size of Texas and bigger than the UK, the Netherlands and Switzerland combined.

Crowded house
2 As well as 400 different types of coral, more than 1,500 species of fish live on the reef. That's approximately ten per cent of the world's total number of fish species.

In the beginning
3 The reef began forming over 20 million years ago. Over time, new coral grew on dead coral and it now covers 348,000km² (134,364mi²) of ocean floor.

Living reef
4 It is the largest structure built by living organisms, and the only living thing on Earth that can be seen from space. It became a UNESCO World Heritage Site in 1981.

Big money
5 It is a popular tourist destination, and attracts over 2 million visitors each year, generating over AU$4mn (£2mn/US$3.2mn) a year for the Australian economy.

DID YOU KNOW? *32 of the 34 recognised phyla of animal can be found on coral reefs, compared to just nine found in rainforests*

Clear waters
Warm water between 21-29°C (70-85°F) is best for coral, as it contains fewer plankton and is clearer, allowing sunlight to penetrate.

9 MILLION
species of undiscovered organisms estimated to be living in reefs

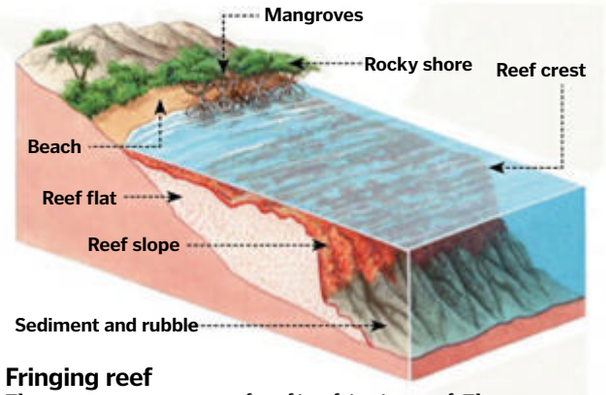
Salty home
Coral can only grow in saltwater, so you'll never find a reef in areas where freshwater rivers flow out into the sea.

Coral colours
Most coral species are yellow or brown, the colour of their symbiotic algae, but others contain colour pigments that help protect them from UV light.

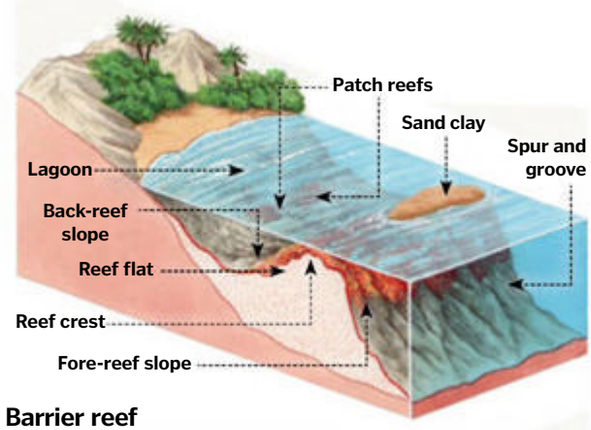
Soft corals
Some coral polyps are joined together by a jelly-like tissue containing spiny skeletal elements instead of a hard skeleton.

4,265 YEARS
The age of the world's oldest coral colony

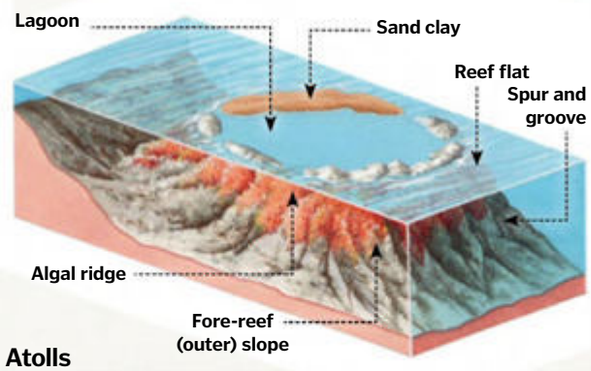
Types of coral reef



Fringing reef
The most common type of reef is a fringing reef. They grow directly from land, creating a border along the shoreline.



Barrier reef
Although they also form parallel to the land, barrier reefs grow further out to sea and are separated from the shore by a lagoon.



Atolls
Over time, a volcano or seamount surrounded by a reef erodes or rising sea levels cause it to flood. This forms an atoll with a lagoon in the centre.

"Coral reefs help to protect shorelines, absorbing 90 per cent of the energy from wind-generated waves"

<0.1%
of the world's ocean floor is covered by coral reefs

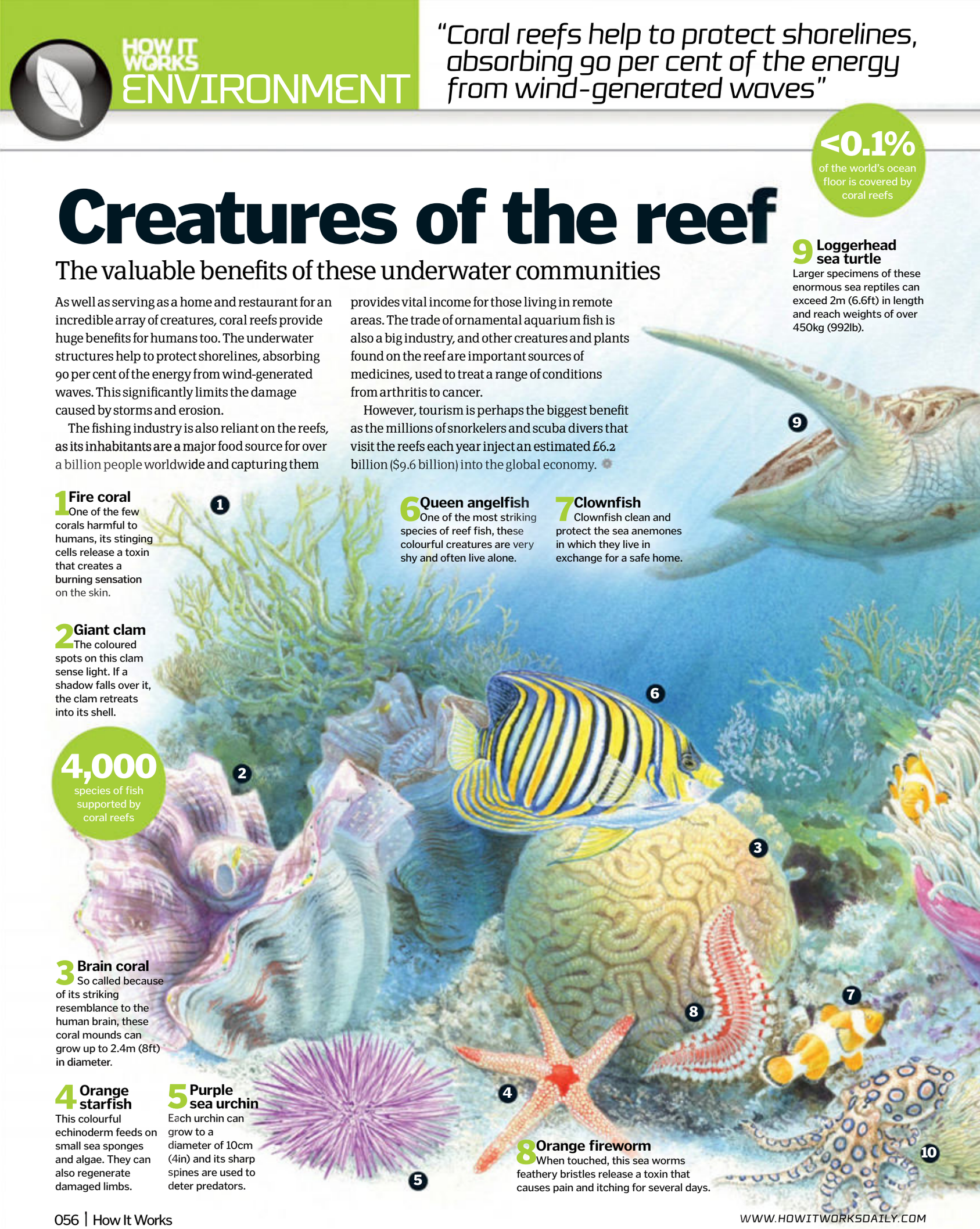
Creatures of the reef

The valuable benefits of these underwater communities

As well as serving as a home and restaurant for an incredible array of creatures, coral reefs provide huge benefits for humans too. The underwater structures help to protect shorelines, absorbing 90 per cent of the energy from wind-generated waves. This significantly limits the damage caused by storms and erosion.

The fishing industry is also reliant on the reefs, as its inhabitants are a major food source for over a billion people worldwide and capturing them provides vital income for those living in remote areas. The trade of ornamental aquarium fish is also a big industry, and other creatures and plants found on the reef are important sources of medicines, used to treat a range of conditions from arthritis to cancer.

However, tourism is perhaps the biggest benefit as the millions of snorkelers and scuba divers that visit the reefs each year inject an estimated £6.2 billion ($9.6 billion) into the global economy.



1 Fire coral
One of the few corals harmful to humans, its stinging cells release a toxin that creates a burning sensation on the skin.

2 Giant clam
The coloured spots on this clam sense light. If a shadow falls over it, the clam retreats into its shell.

4,000
species of fish supported by coral reefs

3 Brain coral
So called because of its striking resemblance to the human brain, these coral mounds can grow up to 2.4m (8ft) in diameter.

4 Orange starfish
This colourful echinoderm feeds on small sea sponges and algae. They can also regenerate damaged limbs.

5 Purple sea urchin
Each urchin can grow to a diameter of 10cm (4in) and its sharp spines are used to deter predators.

6 Queen angelfish
One of the most striking species of reef fish, these colourful creatures are very shy and often live alone.

7 Clownfish
Clownfish clean and protect the sea anemones in which they live in exchange for a safe home.

8 Orange fireworm
When touched, this sea worms feathery bristles release a toxin that causes pain and itching for several days.

9 Loggerhead sea turtle
Larger specimens of these enormous sea reptiles can exceed 2m (6.6ft) in length and reach weights of over 450kg (992lb).

HEAD 2 HEAD
SNEAKY REEF CREATURES

1. SNEAKY

Banded sea krait
This sea snake mimics the movements of its head with its tail, making predators think it is looking right at them while it is actually foraging for food.

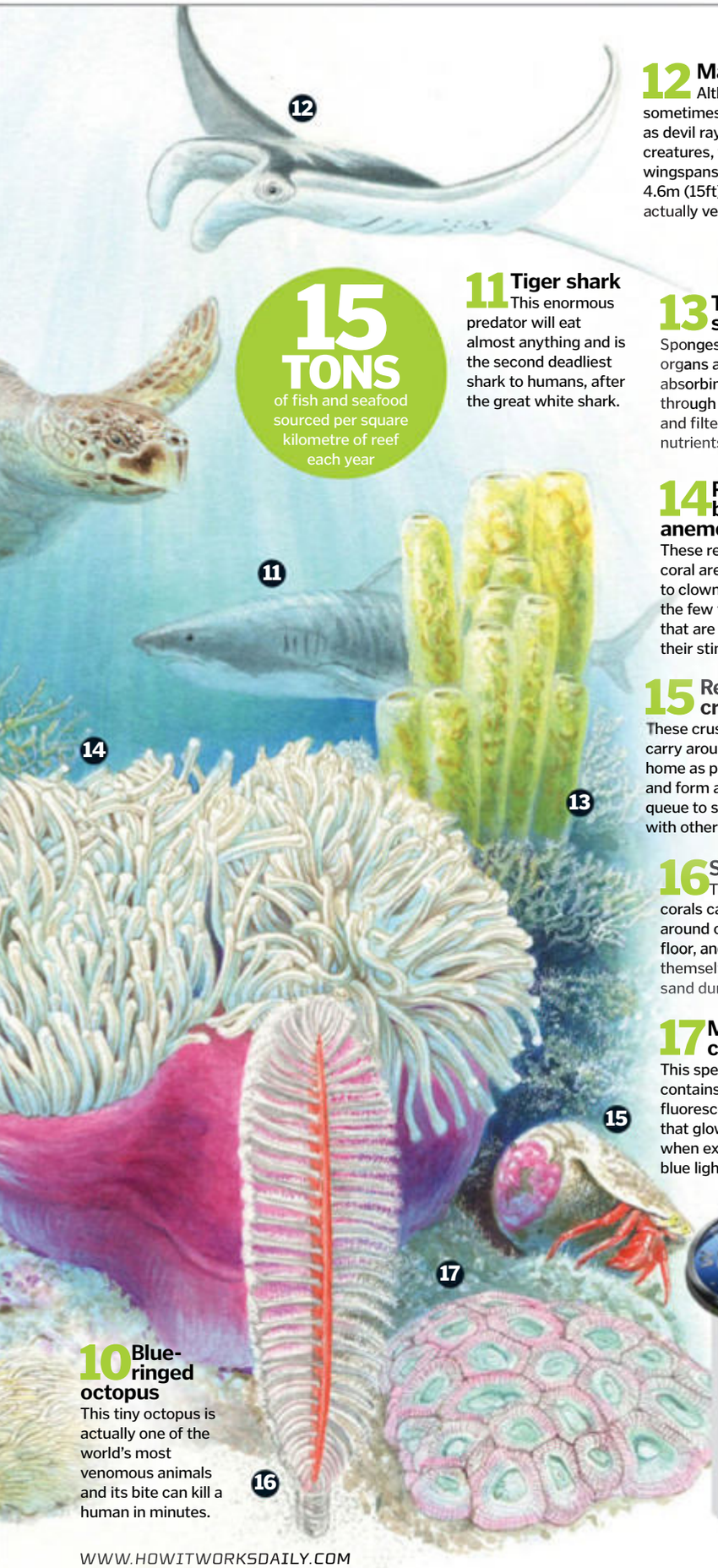
2. SNEAKIER

Nudibranch
These sea slugs eat sponges and recycle their poisonous chemicals to make themselves poisonous and deter predators from eating them.

3. SNEAKIEST

Sponge crab
The sponge crab drags around a living sea sponge on its back, using it as a shield against predators.

DID YOU KNOW? *The limestone skeleton of corals has been tested as bone grafts in humans, as a scaffold for fractures to heal around*



15 TONS of fish and seafood sourced per square kilometre of reef each year

10 Blue-ringed octopus
This tiny octopus is actually one of the world's most venomous animals and its bite can kill a human in minutes.

11 Tiger shark
This enormous predator will eat almost anything and is the second deadliest shark to humans, after the great white shark.

12 Manta ray
Although sometimes referred to as devil rays, these creatures, which have wingspans of over 4.6m (15ft), are actually very gentle.

13 Tube sponge
Sponges have no organs and feed by absorbing water through their pores and filtering the nutrients.

14 Purple base anemone
These relatives of coral are often home to clownfish, one of the few fish species that are immune to their sting.

15 Red hermit crab
These crustaceans carry around a shell home as protection, and form an orderly queue to swap shells with other crabs.

16 Sea pen
These soft corals can move around on the ocean floor, and often bury themselves in the sand during the day.

17 Moon coral
This species of coral contains a fluorescent protein that glows green when exposed to blue light.

Protecting coral reefs

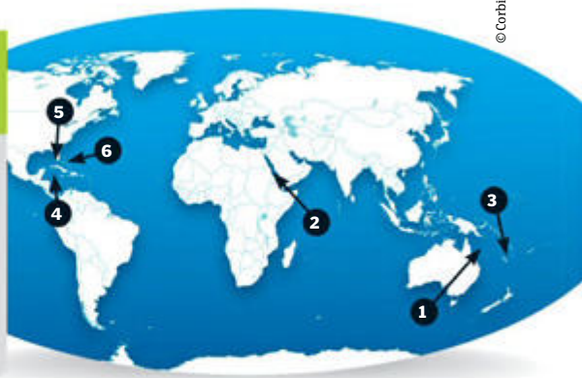
There are a number of factors threatening the world's coral reefs. Global climate change is causing sea temperatures to rise and the water to become more acidic, and coastal agriculture, deforestation and urbanisation is resulting in an increase in sediment and other pollutants seeping into the ocean. Both of these factors are altering the coral's habitat, causing it to expel its symbiotic algae and lose its main source of food in a process known as coral bleaching. Over-fishing is also disrupting the delicate reef ecosystem and nets and boats can often damage the coral too.

Many coral reefs now fall within marine protected areas (MPAs), with coastal and fishing-management strategies implemented in order to prevent further damage. Attempts are also being made to try to restore sick reefs with a process called mineral accretion. It involves submerging a metal structure that has a low-voltage electric current running through it into the water. The current causes natural minerals in the seawater to adhere to it and crystallise forming hard shells similar to that of coral. These structures soon become home to fish and other marine life. Some scientists are also trying to crossbreed hardier species of coral and introduce tough new species into reefs with the hope that they can survive the effects of climate change.

Mineral accretion forms a composite of limestone and brucite, which resembles natural coral

ON THE MAP

The world's largest coral reefs
1. Great Barrier Reef
2. Red Sea Coral Reef
3. New Caledonia Barrier Reef
4. Mesoamerican Barrier Reef
5. Florida Reef
6. Andros Barrier Reef



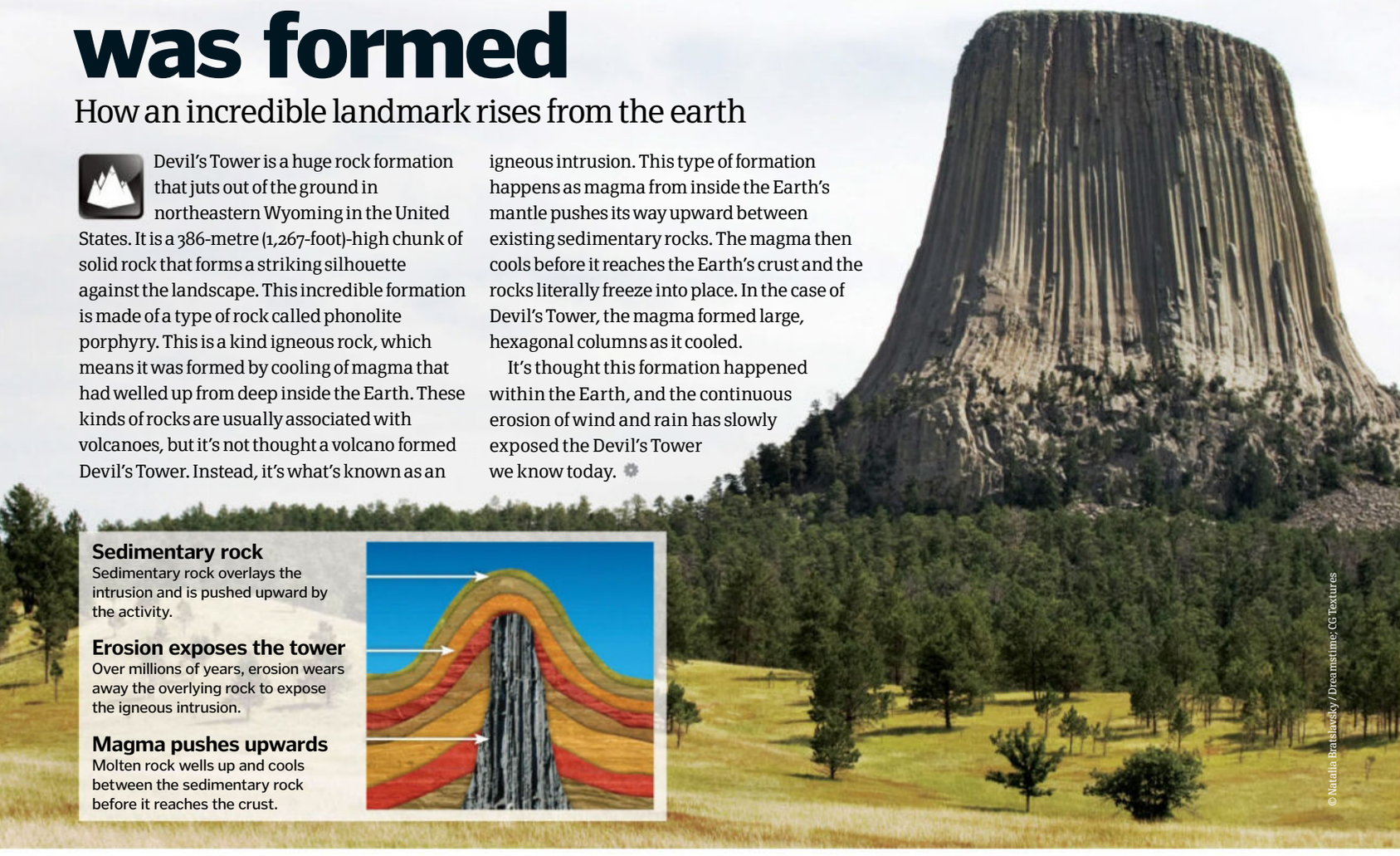
"New species of orchid are being discovered every year, adding to some 25,000 already accounted for"

How Devil's Tower was formed

How an incredible landmark rises from the earth

Devil's Tower is a huge rock formation that juts out of the ground in northeastern Wyoming in the United States. It is a 386-metre (1,267-foot)-high chunk of solid rock that forms a striking silhouette against the landscape. This incredible formation is made of a type of rock called phonolite porphyry. This is a kind igneous rock, which means it was formed by cooling of magma that had welled up from deep inside the Earth. These kinds of rocks are usually associated with volcanoes, but it's not thought a volcano formed Devil's Tower. Instead, it's what's known as an igneous intrusion. This type of formation happens as magma from inside the Earth's mantle pushes its way upward between existing sedimentary rocks. The magma then cools before it reaches the Earth's crust and the rocks literally freeze into place. In the case of Devil's Tower, the magma formed large, hexagonal columns as it cooled.

It's thought this formation happened within the Earth, and the continuous erosion of wind and rain has slowly exposed the Devil's Tower we know today.



Sedimentary rock
Sedimentary rock overlays the intrusion and is pushed upward by the activity.

Erosion exposes the tower
Over millions of years, erosion wears away the overlying rock to expose the igneous intrusion.

Magma pushes upwards
Molten rock wells up and cools between the sedimentary rock before it reaches the crust.

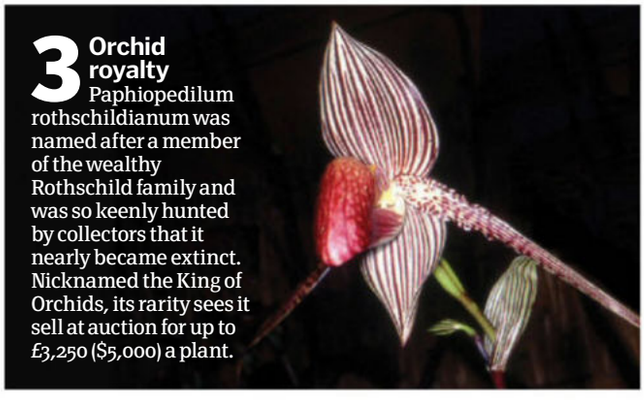
5 facts about orchids

Blooming unbelievable traits of these beautiful, rare and exotic flowers

1 A rare beauty
The ghost orchid (Epipogium aphyllum, right) is among the rarest in the world. Strangely, this plant contains no chlorophyll and only grows tiny scale-like leaves, so it has to rely on an array of symbiotic fungi for nourishment.

2 Medicinal wonder
Orchids have been used in traditional Chinese medicine for centuries. Dendrobium nobile is used to combat kidney disease, while Cremastra appendiculata, known as the Chinese tulip, is supposed to tackle tonsillitis and even cancers.

3 Orchid royalty
Paphiopedilum rothschildianum was named after a member of the wealthy Rothschild family and was so keenly hunted by collectors that it nearly became extinct. Nicknamed the King of Orchids, its rarity sees it sell at auction for up to £3,250 ($5,000) a plant.



4 More various than birds
New species of orchid are being discovered each year, adding to some 25,000 already accounted for – twice as many as there are species of bird. Estimates show that about 5,000 orchid varieties remain undiscovered.

5 Human likeness
The bilateral symmetry of an orchid flower gives it a similar basic shape to a human face. It's been suggested this is what has led the plants to be so popular and sought after by collectors.

5 TOP FACTS
TEA STORY

Origins
1 The drink we know and love as tea was reportedly created over 5,000 years ago in China, enjoyed under the Chinese emperor Shen-Nung.

Arrival in Europe
2 Tea arrived in Europe around 1560 and the first advertisement for tea in the UK was in 1658, appearing in an English newspaper.

The nation's favourite
3 By the mid 18th-century tea had become the drink of the masses and now there are 165 million cups drunk daily in the UK – that's around 60.2 billion per year.

Tea bags
4 Invented in the early-20th century in America, putting tea in disposable bags means a cup was now easier to brew. Today, 96 per cent of UK tea is from tea bags.

A richer taste
5 Although tea originated in China, the European market preferred the stronger taste of Indian tea to the finer, more delicate Chinese alternative.

DID YOU KNOW? *Tea provides a source of manganese and potassium, which your body needs for growth and development*

Where does tea come from?

Follow the journey from the field to the teacup

Tea, the hot beverage enjoyed so much in the UK that it has become as quintessentially British as the Queen, begins its life as juicy young leaves on a bush of the Camellia family. The species Camellia sinensis originates from China and the Camellia sinensis assamica variant is the Indian tea variety. Tea bushes are grown in vast crops in hot, humid areas with regular rainfall. China, India, Sri Lanka and Kenya are the top four countries, representing 75 per cent of the world's tea production. Factors such as climate, altitude and humidity affect the quality and taste of the tea crop – much in the same way as grapes and wine – and their leaves are expertly selected and plucked by hand.

Black tea, the kind you're probably enjoying with milk and one sugar as you read this, is made from new, tender tea shoots, typically the first few leaves and a bud. Once picked, the leaves go through four main steps before they're ready for brewing in a teapot and accompanying some afternoon cake: withering, rolling, oxidation and drying. For different tea varieties, these steps are modified and adapted, which helps to produce such a huge array of different tea flavours and types.

The plant
Tea leaves grow on bushes in vast crops. If left untended the tea plant could reach up to 20m (65ft) tall, but the bushes are usually pruned at the 'plucking table' around 1.2m (4ft) – this helps hand-picking and promotes bud growth.

Plucking
Leaves are never plucked from the plant individually; they are always removed as a group of one, two or three leaves along with the bud that forms at the end of the stem.

Withering
The freshly picked leaves are laid out in large troughs or shelves to wither for eight to 12 hours. Air is often passed through in order to help the removal of moisture, and after withering the leaves look wilted.

Rolling
The leaves are broken up and the enzymes are released in preparation for oxidation. There are two rolling methods: Orthodox, where rollers gently break leaves; and CTC – cut, tear, curl – where leaves are cut by a machine.

Packaging
After the tea is dried, it is sorted into grades depending on the dried leaf's size. Larger leaves are sold for loose-leaf tea and smaller ones are prepped for use in tea bags.

The cup
The tea is then ready for brewing. The dried tea leaves infuse hot water with the delicate taste that's governed by the growing conditions and careful preparation process. Pop the kettle on!

Drying
Tea leaves are then dried in order to stop the oxidation process at precisely the right time to make sure the tea's flavour is just right. The oxidised leaves are gently heated to remove all excess moisture.

Oxidising
The withered and rolled tea leaves are laid out for a few hours to oxidise, which means they react with oxygen and begin to ferment. The leaves undergo chemical processes where they partially break down.

Different types of tea

The four main types of tea are black tea, green tea, white tea and oolong tea. They all originate from the same plant, and it is their preparation that defines their taste. White teas only use the very first buds at the top of a new season's tea plant, which can only be plucked once a year.

All four types of tea leaves are withered first – a process that reduces the moisture content. Once withered, leaves for making green tea are then steamed or pan-fried. This stops the oxidation process – meaning there is no further reaction with oxygen – which is why the leaves keep their natural green colour, giving the tea its name.

Oolong tea is semi-oxidised, placing it somewhere between green and black tea. The partial oxidation allows the leaves to briefly ferment, producing a more distinctive flavour. The leaves are then rolled and dried ready for brewing.

"Wading birds take full advantage of the rich pickings in the nutrient-laden mud"

Wildlife of the Orinoco plains

Weaving through South America, the Orinoco River creates a unique habitat for giant anacondas, piranhas and more

The Orinoco River begins at its source in the Guiana Highlands, and then curves its way through Venezuela and Colombia until finally meeting the Atlantic Ocean. Along the river's route, there are rolling grasslands, marshes and forests, known as plains, or Los Llanos.

The tropical savannah climate of the marshes and swamps that fringe the wide-open grasslands are a perfect habitat for thousands of freshwater dwellers. Catfish, piranhas, giant otters and giant anacondas are just a few of the critters lurking beneath the surface. Wading birds also take full advantage of the rich pickings in the nutrient-laden mud, such as ibises that use their curved beaks to dig out a tasty crustacean dinner.

The gallery forests surrounding the plains provide plenty of shelter and cover for more elusive hunters. Jaguars are known to skulk around the trees, and thousands of bird species roost in the canopy. One of the tallest trees is the moriche palm, which can reach 35 metres (114 feet).

In spring, herds of deer graze the savannah, which is often flooded during the rainy season and extends the habitat of the water-dwelling Llanos residents. The grasses are also the perfect habitat for species such as giant anteaters that seek out termites, as well as birds like the northern screamer and the burrowing owl, which hunts small reptiles and mammals and excavates a burrow as a nest.

The Llanos biome is also an important habitat for migratory species, with an estimated 40 per cent of Colombia and Venezuela's Neotropical migratory bird species residing on the Orinoco plains throughout the year.

Peregrine falcon
As one of the fastest birds on Earth, an attacking falcon can reach speeds of over 300km/h (186mph).

Wildfires help to regulate the landscape and promote new growth

Natural fires

During the dry season, from November through March or April, the Llanos can become quite parched. Very little rainfall means the Orinoco River waters are at their lowest, while soaring temperatures dry out the vegetation. These combining factors can result in natural fires, which may sound severe but are actually an excellent way for the ecosystem to renew itself.

These savannah fires burn away excess vegetation and expose new ground. This provides more room for new seeds to colonise, which in turn grow to provide the all-important base of the plains' food chain.

Fires can also maintain the nutrient balance of the soil and regulate the growth and advance of trees on the grasslands. Burning away old vegetation allows fresh growth of existing plants. However, some Llanos species have adapted to this natural phenomenon, and so the plains are also populated with species of fire-tolerant trees that can withstand the natural flames,

Endangered species

The plains are home to an amazing array of plants and animals, including over 100 species of mammals and 700 species of birds. They are also a key habitat for some of the most endangered animals on the planet. For example, the Orinoco crocodile that lives on the flooded Llanos during the rainy season is classed as critically endangered by the IUCN Red List of Threatened Species, and is thought to only have around 1,500 individuals left in the wild. Other Llanos species, such as the giant armadillo, Orinoco turtle, giant otter and black-and-chestnut eagle, are also threatened species.

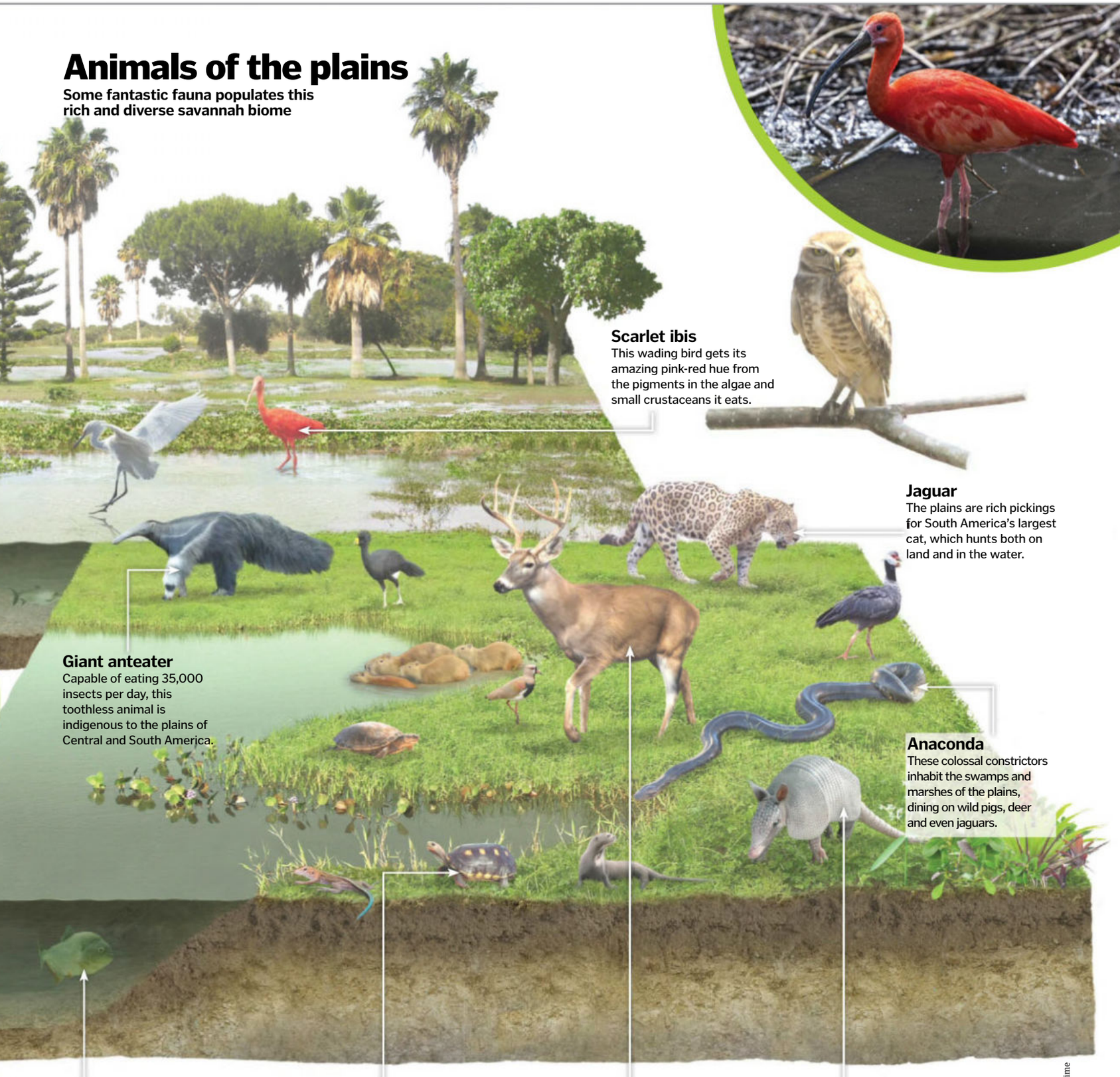
THE STATS
ORINOCO FLOW

RIVER LENGTH: 2,140km
AREA: 569,800km²
TALLEST TREES: 35m
MEAN TEMPERATURE: 27°C
ANNUAL RAINFALL: 850-3,300mm
FISH SPECIES: >1,000

DID YOU KNOW? *The fearsome Orinoco crocodile can reach over 6m (19.7ft) in length!*

Animals of the plains

Some fantastic fauna populates this rich and diverse savannah biome



Scarlet ibis
This wading bird gets its amazing pink-red hue from the pigments in the algae and small crustaceans it eats.

Jaguar
The plains are rich pickings for South America's largest cat, which hunts both on land and in the water.

Giant anteater
Capable of eating 35,000 insects per day, this toothless animal is indigenous to the plains of Central and South America.

Anaconda
These colossal constrictors inhabit the swamps and marshes of the plains, dining on wild pigs, deer and even jaguars.

Black spot piranha
Living in large shoals, the piranha uses its needle-like teeth to munch on birds, crustaceans and vegetation.

Red-footed tortoise
Living on the savannah grasslands and edges of the forests, these medium tortoises exist on an omnivorous diet.

White-tailed deer
Herds of these deer can be found grazing the rich grasslands of the Llanos.

Giant armadillo
These armoured critters can reach up to 150cm (59in) in length and are considered ecosystem engineers due to their digging excavations.

"It can be months or even years before some species reach the metamorphosis stage"

From egg to adult

Take a closer look at the journey of a dragonfly

1 Mating adults
The male dragonfly attaches his abdomen to the female's head as she curls hers under, so that he can fertilise the eggs.

2 Depositing the eggs
The female will then submerge her abdomen in water to deposit the eggs. She can lay hundreds of them in a day.

3 Emerging nymphs
After a week the nymph will emerge from the egg and remain in the water for a few months to a couple of years, surviving off other insects and small vertebrates.

4 Instar stages
The nymph will go through several instars before it reaches the metamorphosis stage. It will shed its exoskeleton each time to make room for growth.

5 Shedding the exoskeleton
Once ready the nymph will emerge from the water and attach to a nearby plant. The puffy exoskeleton will then split open.

6 Emerging dragonfly
The still-vulnerable young adult dragonfly carefully curls out of its split exoskeleton.

7 Drying out
Before flying away, the dragonfly will wait for its legs to harden and for its wings to unfurl and dry out in the Sun.

Some species of dragonfly will change colour over time

The life cycle of a dragonfly

Discover how the dragonfly develops underwater and emerges as a magnificent flying predator

As the dragonfly mating season gets into full swing during the summer months, streaks of colour can be seen dashing across the sky. This is just the start of their long life cycle and it all begins midair, as the male dragonfly pursues a mate. Females can lay hundreds of eggs throughout their lives, depositing them in or on the surface of a nearby lake, stream or pond. It will take up to a week for the nymphs to emerge from the eggs and then it can be months or even years before some species reach the metamorphosis stage.

In the meantime, the nymphs will continue to develop underwater, breathing through gills in their body and feeding off other insects and even live tadpoles and small fish. Unlike butterflies, dragonflies do not have a pupal stage. Instead, they emerge from the water where their exoskeleton cracks open and releases the insect's four wings. The process takes about three hours to complete and then the young dragonfly must wait hours, or even days, for their wings to dry and harden. Their first flight usually only covers a few metres but soon they'll be hurtling forward at speeds of 56 kilometres (35 miles) per hour, hovering for up to one minute and even flying backward or upside down.

Incidentally, dragonflies were among the first insects in the history of Earth to gain the ability to fly, existing about 300 million years ago with wingspans of 68 centimetres (26.8 inches). Today there are about 3,000 species in the world and their incredibly complex and well-choreographed reproduction method will secure this insect's presence for years to come.

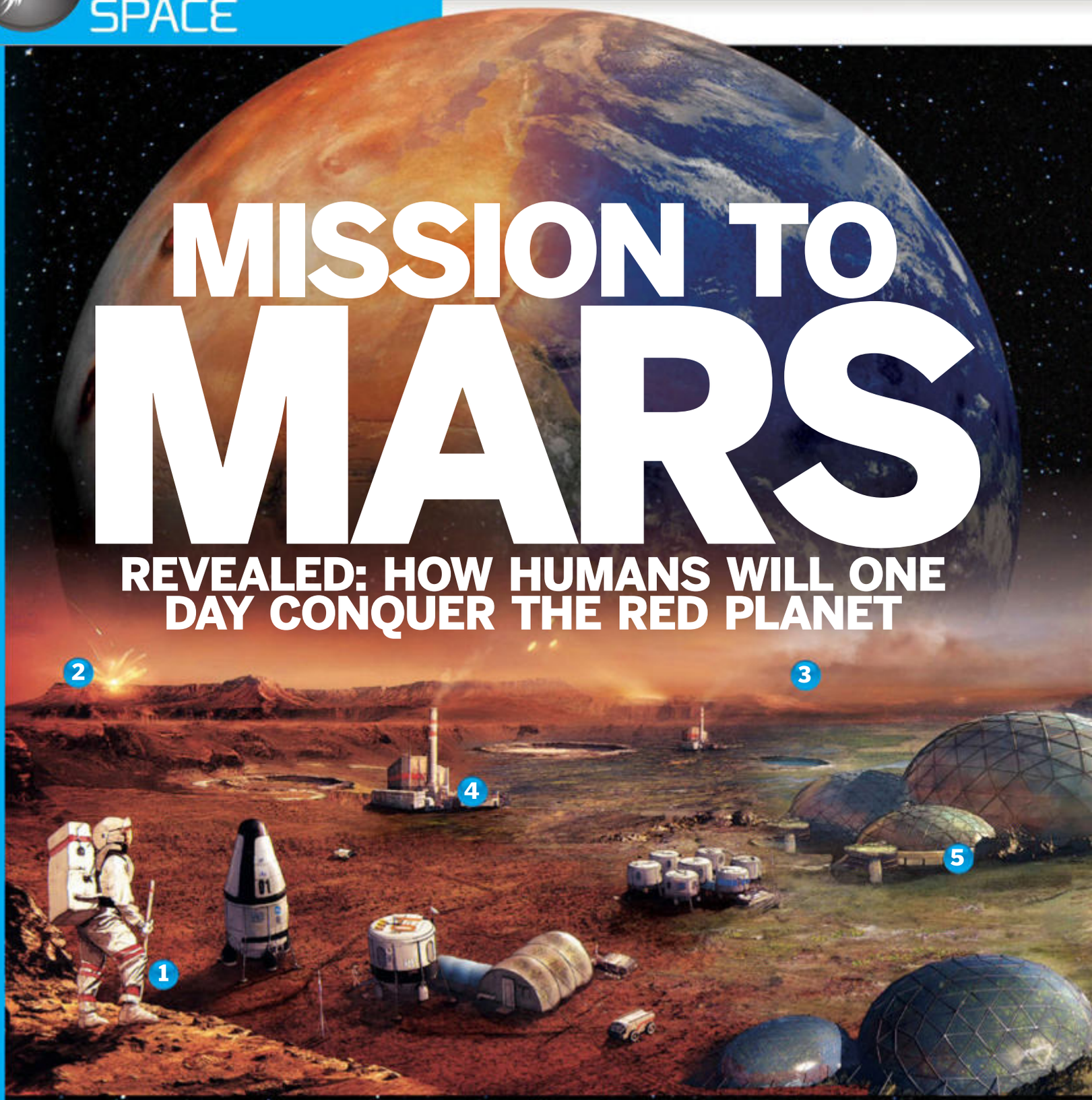
Developing colour

Young adult dragonflies have very muted colours and faint markings when they first emerge from their exoskeleton. It can take days for them to gain their full vibrant colour, as their bodies still need to harden in the Sun. Temperatures can also affect how strong colours and patterns appear, and the adult males are generally brighter and bolder in colour than the females.

Of course, strong vivid colours make it difficult for the dragonfly to remain inconspicuous, but its unique colour and pattern markings aren't meant for camouflage. In fact, it helps the dragonfly survive as it warns potential predators that the insect may be poisonous. However, as the dragonfly ages, colours can fade or even change completely. The common darter dragonfly, for example, will go from yellow to red.

MISSION TO MARS

REVEALED: HOW HUMANS WILL ONE DAY CONQUER THE RED PLANET



1 Earth-like conditions
Conditions on Mars are more similar to Earth than they are on any other planet or moon we know of. However, it is still not hospitable to humans, being too cold and with a thin carbon dioxide atmosphere.

2 Comet crashes
One way to thicken Mars' atmosphere is to redirect comets and asteroids to crash into its surface. This would release gases from both the impactor and the surface, as well as create heat.

3 Thicken the atmosphere
The atmospheric surface pressure on Mars is only 0.6 per cent of that on Earth. The first task in terraforming is to make the atmosphere thicker, to warm the planet and allow water to exist on the surface in liquid form.

4 Factories
On Earth, pollution from factories is bad for the environment, but if we want to terraform Mars we need to pump out huge amounts of greenhouse gases to thicken the atmosphere and trap the Sun's heat in the greenhouse effect.

5 Radiation
One thing terraforming cannot fix is Mars' lack of a magnetic field, which could help block deadly radiation from space. Colonists may have to live in large shielded habitats to protect themselves from the radiation.

THE STATS
MARS FIGURES

AVERAGE TEMPERATURE **-63°C**

DIAMETER OF MARS **6,779km**

LENGTH OF MARS' YEAR **687** Earth days

24h 40min LENGTH OF MARS' DAY

GRAVITATIONAL ACCELERATION **3.7m/s²** (38% of Earth's gravity)

COMMUNICATION DELAY BETWEEN EARTH AND MARS Minimum 4min, maximum 24min

DID YOU KNOW? *A day on Mars is 24 hours and 40 minutes, which means astronauts will have to use different watches*

It's the planet on the bucket list of future astronauts. The world that will serve as a stepping-stone, taking humans farther out into space. It might be dry, barren and home to long-dead landers and resilient rovers that trundle along its surface, but Mars has potential. Potential to join Earth in being the only other planet in our Solar System to have life as we know it on its surface.

"Mars is the closest planet that has all of the resources to support life on it and potentially a new generation of human civilisation," says The Mars Society's Dr Robert Zubrin, an American aerospace engineer who advocates the manned exploration of Mars. "Mars can help us to discover the phenomena of life specific to Earth and general phenomena in the universe." Zubrin makes it sound surprisingly easy to colonise the Red Planet. But despite the obvious differences between it and Mother Earth, Mars also holds several similarities that make it the most obvious option for light years around. First, there's water, mostly at the planet's poles; the gravity is only 2.6 times less than that of Earth's and what's more, a Martian day is only 40 minutes longer than a day on our planet. With an average temperature of -62 degrees Celsius (-81 degrees Fahrenheit), you'd need to wrap up against the cold, but even in these teeth-chattering conditions, it is still our best shot at attempting to venture out into the Solar System.

However, while there's a degree of familiarity, the fourth rock from the Sun harbours much of the unknown – something that could make us hesitant about setting foot on Martian soil. "The most important factor needed is the courage to try", Zubrin tells us. "Can humans live on Mars? That can only really be determined by sending people there. If Barack Obama got up tomorrow and said: 'I'm committing the nation to sending humans to Mars', we could have people on the Red Planet by the end of the decade." ▶

Making oxygen for Mars

The Mars 2020 rover mission will have a similar design to the Curiosity rover

In 2020, NASA aims to send another rover to the Red Planet. However, while it will be built much like Curiosity, it is tipped to do something no other rover has done before: it will make oxygen.

The piece of technology that aims to do this is the Mars OXygen In-situ resource utilization Experiment, or MOXIE for short. Using the gas that's the most abundant on the Red Planet – carbon dioxide – the instrument will make oxygen and carbon monoxide before releasing it into the atmosphere. MOXIE should produce 22 grams (0.8 ounces) of oxygen per hour over 50 Martian days.

If MOXIE works well, we will be landing a larger instrument just like MOXIE on Mars along with a nuclear reactor to power it. This would fill an oxygen reservoir, which astronauts would breathe in when they arrive on the Red Planet. It could also be possible to use this oxygen as a rocket propellant to power their return trip to Earth.

Humans on Mars

Mars does not have a habitable environment, but terraforming could make it more Earth-like

6 Gravity
Gravity is a problem – Mars' gravity is only 38 per cent of Earth's gravity, meaning Mars finds it harder to hold onto its atmosphere. The atmosphere will have to be constantly replenished if we are to terraform Mars.

7 Martian algae
The introduction of algae could have benefits. It can break down carbon dioxide to make oxygen to breathe, and its dark colour could help lower Mars' albedo, helping Mars trap more of the Sun's heat rather than reflecting it back into space.

8 Turning the red planet blue
Mars has vast amounts of water frozen as ice, both in its polar caps as well as underground, all the way down to the mid-latitudes. Increasing the pressure and temperature on Mars will allow this ice to melt to form lakes and rivers.

9 Bringing life to a dead planet
As far as we know, Mars is a dead planet. Terraforming Mars could make it possible for us to introduce life and grow plants in the Martian dirt.

10 No more spacesuits
The aim of terraforming is to create an environment on Mars where colonists will be able to survive outside without space suits, at least for a short time.

"The rovers are the advance scouts, but there's nothing they can do that we could not do a thousand times faster"

Preparing for the journey

Brave volunteers are undergoing intense experiments to discover what it takes

"Looking for life in the past, looking for life in the present and determining the future of humanity on Mars means we have to send people there," says Robert Zubrin. That means preparation is key if we're ever going to set foot on this other world. We've sent spacecraft and rovers to the Red Planet to shape our understanding of it. The Mars Reconnaissance Orbiter, which clutches the HiRISE camera, is currently in orbit around Mars, taking snaps of the landscape to identify the best possible location for future colonists.

Rovers Opportunity and Curiosity are tasting the Martian atmosphere and sampling the planet's soil in a bid to find out more details, supplying crucial information for the first Mars-walkers. "The rovers are the advance scouts, but there's nothing they can do that we could not do a thousand times faster," Zubrin adds. That's why we've had to start making some headway in preparing future Martian astronauts for a mission that will be as big as the day we first landed a man on the Moon.

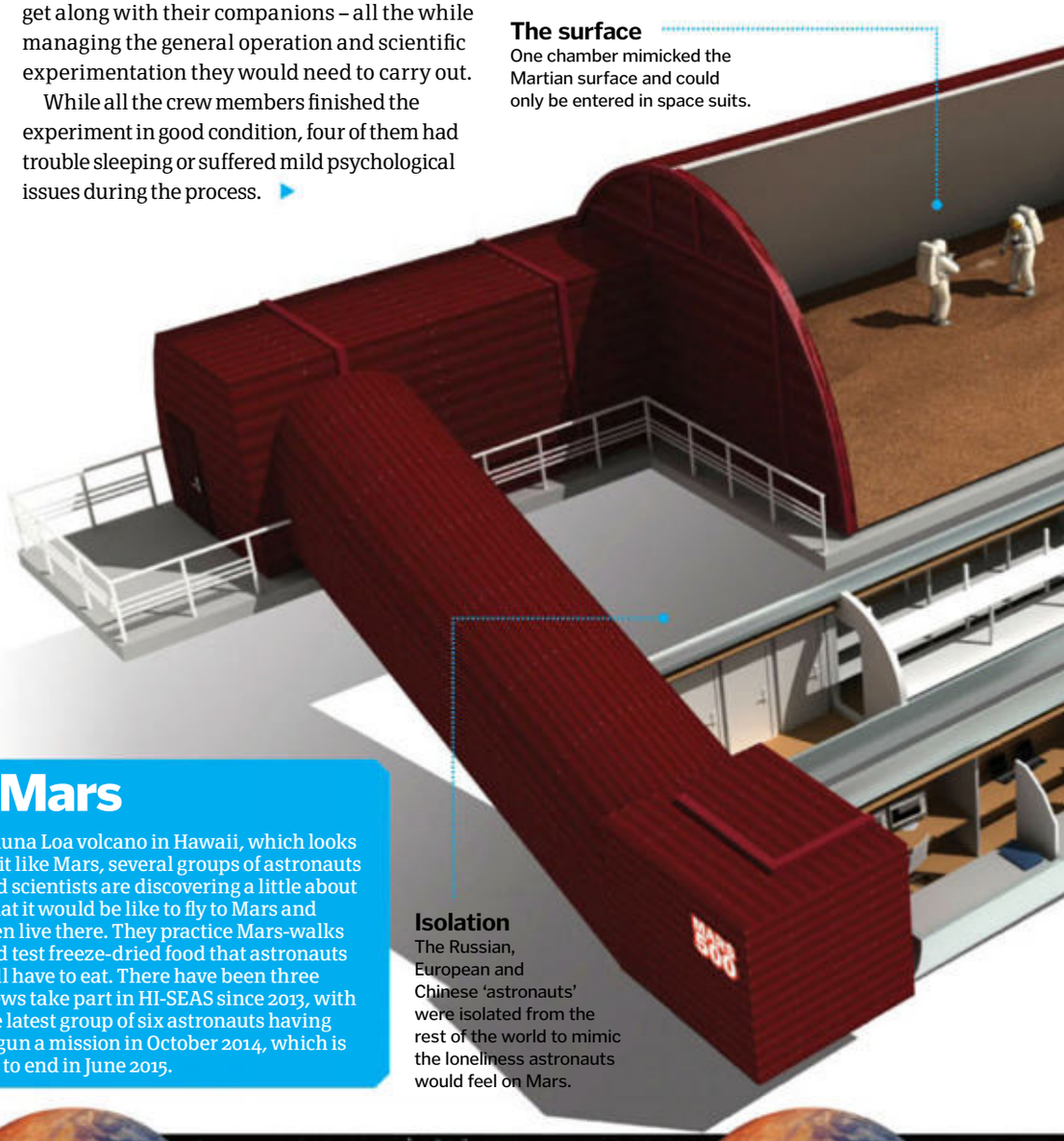
That's where facilities on Earth have come in until we're fully ready to make our way to Mars. A joint effort between Russia, ESA and China, 2010's Mars500 was a project like no other. It tested the psychological mettle of its crew to the limit, squeezing six volunteers into cramped quarters of 550 cubic metres (19,423 cubic feet) for a total of 520 days on a simulated mission to Mars.

Being roughly 260 days away, astronauts to Mars would get the same treatment for real. They would need to be able to withstand the isolation, the confined space, the delayed communication between them and Earth and get along with their companions – all the while managing the general operation and scientific experimentation they would need to carry out.

While all the crew members finished the experiment in good condition, four of them had trouble sleeping or suffered mild psychological issues during the process.

500 days on 'Mars'

A multinational experiment saw potential Mars astronauts spend 520 days isolated in a mock Martian base



The surface
One chamber mimicked the Martian surface and could only be entered in space suits.

Isolation
The Russian, European and Chinese 'astronauts' were isolated from the rest of the world to mimic the loneliness astronauts would feel on Mars.

Making the trip to Mars

The journey to Mars will take astronauts around seven months, and crews could remain there for roughly two years – until Earth and Mars are closest to each other in their orbits again for the return trip. Finding out more about how such a long voyage will affect astronauts is the Hawaii Space Exploration Analog and Simulation project, also known as HI-SEAS. All alone on the slopes of the Mauna Loa volcano in Hawaii, which looks a bit like Mars, several groups of astronauts and scientists are discovering a little about what it would be like to fly to Mars and then live there. They practice Mars-walks and test freeze-dried food that astronauts will have to eat. There have been three crews take part in HI-SEAS since 2013, with the latest group of six astronauts having begun a mission in October 2014, which is set to end in June 2015.

1965

The first space mission to successfully reach Mars is Mariner 4, which shows the Red Planet is barren and lifeless.

1969

Astronauts Neil Armstrong and Buzz Aldrin land on the Moon, becoming the first humans to set foot on another world.

Buzz Aldrin stood on the Moon. Could astronauts one day stand on Mars?

1976

The Viking landers and orbiters transform what we know about Mars, finding ancient riverbeds and searching for life on the surface.

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Learn about the Orion capsule that NASA will use

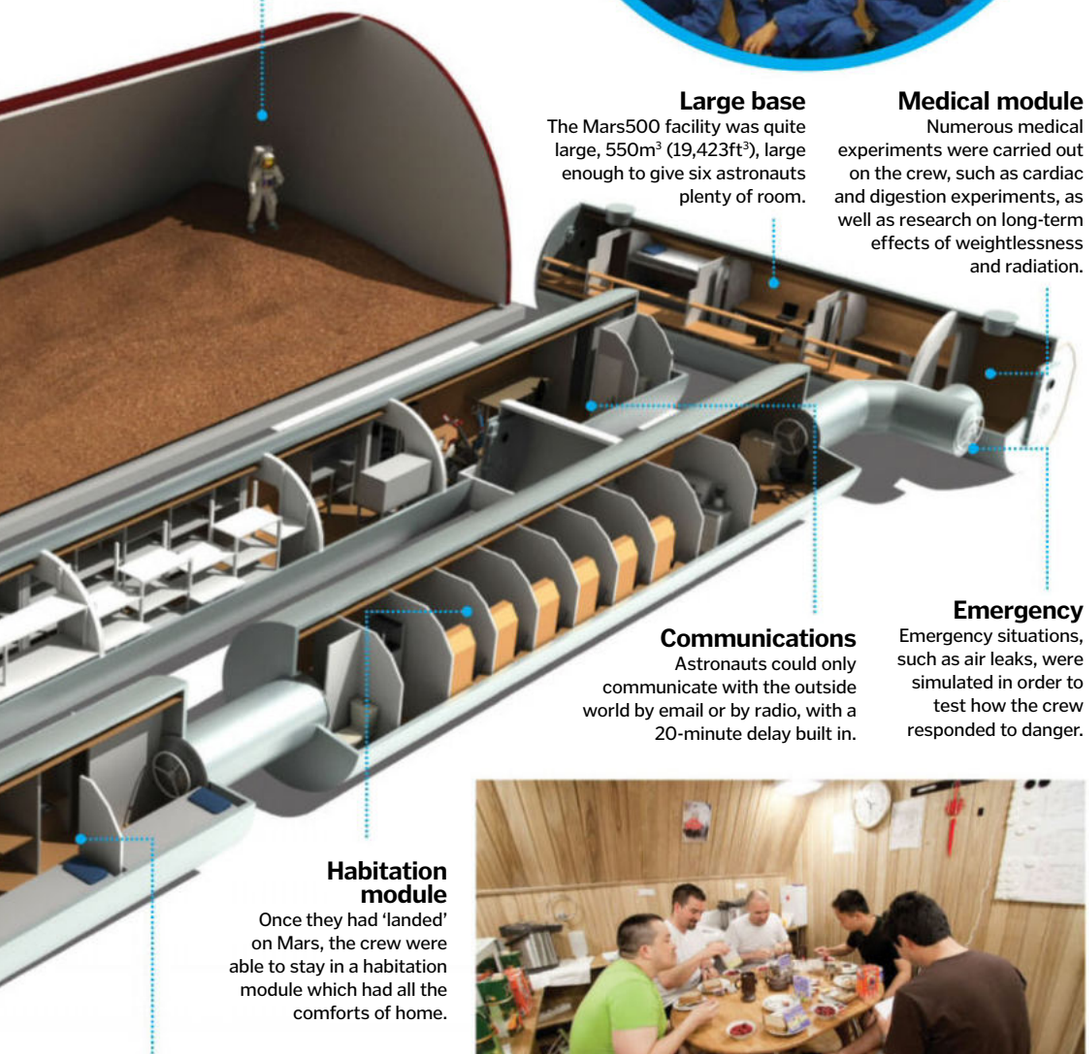
www.howitworksdaily.com

DID YOU KNOW? *Martian dust storms can envelop the entire planet, so colonists will have to stay in their habitats for safety*

The crew of the Mars500 experiment, during their 'return' journey

Skills

Mars500 astronauts had to be between the ages of 25 and 50, have academic qualifications and be specialists in engineering, biology or medical skills, and be multilingual.



Large base

The Mars500 facility was quite large, 550m³ (19,423ft³), large enough to give six astronauts plenty of room.

Medical module

Numerous medical experiments were carried out on the crew, such as cardiac and digestion experiments, as well as research on long-term effects of weightlessness and radiation.

Communications

Astronauts could only communicate with the outside world by email or by radio, with a 20-minute delay built in.

Emergency

Emergency situations, such as air leaks, were simulated in order to test how the crew responded to danger.

Habitation module

Once they had 'landed' on Mars, the crew were able to stay in a habitation module which had all the comforts of home.

Landing craft

After they'd 'arrived' at Mars the crew had to spend 30 days in the Landing Module Simulator while 'on planet'.

The Mars500 chamber provides a homely environment for the astronauts stuck on their 'journey'

Simulating Mars on Earth

Austrian Space Forum's Gernot Groemer on the Mars2013 project

Could you briefly describe what the Mars2013 expedition entailed?

Directed by a mission support centre in Austria, a small field crew conducted experiments preparing for future human Mars missions, mainly in the fields of engineering, planetary surface operations, astrobiology, geophysics/geology, life sciences and others. We had a truly international team from 23 countries, involving more than 100 researchers and volunteers, including the United Kingdom.

What did you learn from your expedition?

We had 17 peer-reviewed research experiments and collected a large data set. One of the major outcomes was that we have gained a lot of operational experience in conducting human exploration activities on the surface of another world.

Do you think humans are ready for a trip to Mars?

Yes. It will be the most technically challenging journey our society has ever undertaken, but from an engineering and scientific point of view, we are almost ready. In all our research we haven't encountered a showstopper that told us "no, you can't go."

What do you think the future holds for manned exploration of the Red Planet?

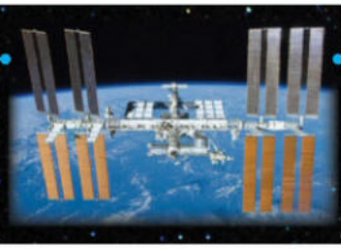
At the Austrian Space Forum we say the first human to walk on Mars is already born. I personally believe this generation will be the first one to be able to tackle the question of life in the universe on a promising planetary surface for the first time. If you read a history book in 200 years from now, the economic crisis might only be a marginal chapter. In the long run, it will be known as the time when we left the planet to discover new worlds.

1997

NASA's Pathfinder mission arrives on Mars with its little Sojourner rover. The rover provides a new, mobile method of exploring Mars.

1998

Construction begins on the International Space Station, which becomes an ideal place for training for long-duration missions such as to Mars.



2004

The Mars exploration rovers Spirit and Opportunity land on Mars and capture the public's imagination with their exploits in exploring the Red Planet.

"To get Orion and the habitation module to their destination will require the biggest rocket since the Saturn V"

Getting to the Red Planet

What will astronauts face during their journey?

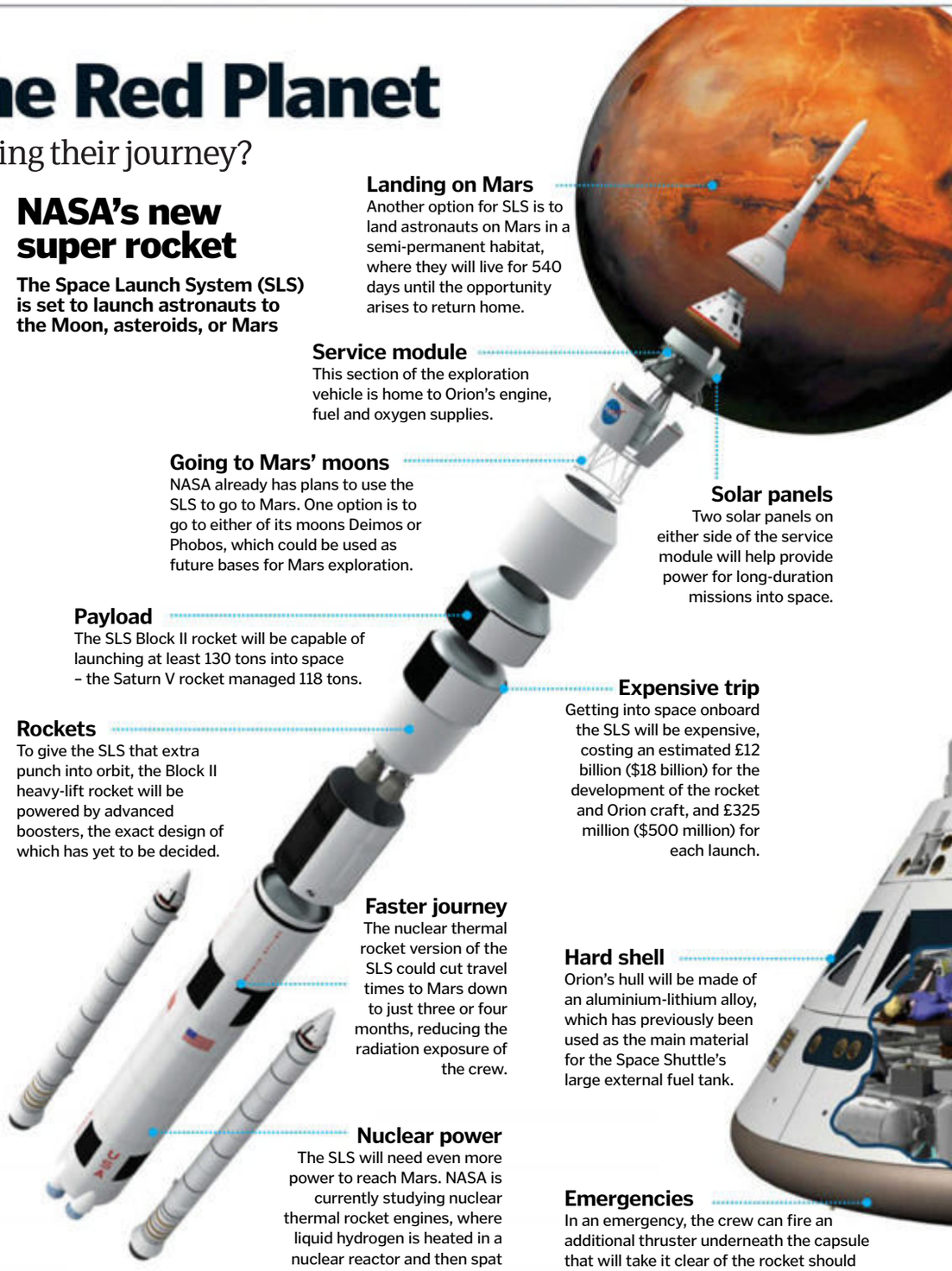
We will soon have the technological capability to go to Mars, thanks to NASA's latest spaceflight system that is under development, the Orion capsule and the Space Launch System, or SLS. Orion is billed as a multi-purpose crew vehicle, and has already experienced test flights with the aim of sending astronauts into space onboard it within the next decade. A little like a bigger, far more sophisticated version of the Apollo capsules that took 24 astronauts to the Moon, Orion by itself is not suitable for a long journey to Mars. However, Orion could hook up with a larger habitation module in orbit around Earth, providing the living space necessary for the astronauts before leaving Earth orbit and heading for Mars.

To get Orion and the habitation module to their destination will require a giant rocket – the biggest since the Saturn V. Simply called the Space Launch System, it will come in a couple of varieties. The first, called Block I, will be able to launch 70 tons into low Earth orbit using Space Shuttle-derived booster rockets. The next version, Block II, will dispense with the shuttle boosters for more advanced rockets, capable of launching 130 tons into space. No other rocket in history has ever been capable of launching such a large payload. The habitat module could be launched in segments and then assembled in space before leaving for Mars on the back of an SLS rocket.

The private space company SpaceX is also keen to get in on the act. Owner of SpaceX, Elon Musk, has said that he wants to start a colony on Mars, and is developing a Mars Colonial Transporter, which Musk says will be capable of launching 100 tons into space. The mission may involve some variation of SpaceX's Dragon capsule that's already ferrying cargo to the International Space Station and could one day be outfitted to carry astronauts too.

NASA's new super rocket

The Space Launch System (SLS) is set to launch astronauts to the Moon, asteroids, or Mars



Landing on Mars
Another option for SLS is to land astronauts on Mars in a semi-permanent habitat, where they will live for 540 days until the opportunity arises to return home.

Service module
This section of the exploration vehicle is home to Orion's engine, fuel and oxygen supplies.

Going to Mars' moons
NASA already has plans to use the SLS to go to Mars. One option is to go to either of its moons Deimos or Phobos, which could be used as future bases for Mars exploration.

Solar panels
Two solar panels on either side of the service module will help provide power for long-duration missions into space.

Payload
The SLS Block II rocket will be capable of launching at least 130 tons into space – the Saturn V rocket managed 118 tons.

Expensive trip
Getting into space onboard the SLS will be expensive, costing an estimated £12 billion ($18 billion) for the development of the rocket and Orion craft, and £325 million ($500 million) for each launch.

Rockets
To give the SLS that extra punch into orbit, the Block II heavy-lift rocket will be powered by advanced boosters, the exact design of which has yet to be decided.

Faster journey
The nuclear thermal rocket version of the SLS could cut travel times to Mars down to just three or four months, reducing the radiation exposure of the crew.

Hard shell
Orion's hull will be made of an aluminium-lithium alloy, which has previously been used as the main material for the Space Shuttle's large external fuel tank.

Nuclear power
The SLS will need even more power to reach Mars. NASA is currently studying nuclear thermal rocket engines, where liquid hydrogen is heated in a nuclear reactor and then spat out to provide thrust.

Emergencies
In an emergency, the crew can fire an additional thruster underneath the capsule that will take it clear of the rocket should there be an explosive accident.

2006
NASA's Mars Reconnaissance Orbiter arrives in Mars orbit, taking pictures of the surface to help choose landing sites for manned missions.

Early 2020s
NASA intends to first send its manned Orion capsule to visit a near-Earth asteroid before it sends a mission to Mars.

The first Martian astronauts will live in simple habitation modules, perhaps built out of spaceships.

2030s
For humans to survive on Mars, they will need purpose-built habitat modules and supplies that could be sent to Mars ahead of any crewed mission.

RECORD BREAKERS
LONG-DISTANCE TRAVELLER

42.05km

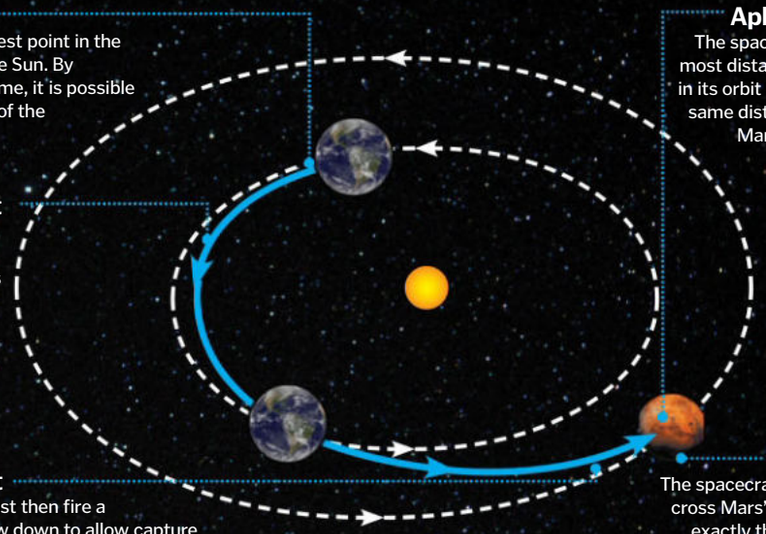
LONGEST DRIVE ON MARS

NASA's Opportunity rover holds the off-Earth distance record after travelling 42.05km (26.13mi) across the surface of Mars, beating Soviet Lunokhod 2 lunar rover, which travelled 39km (24.2mi) in 1973.

DID YOU KNOW? *Mars soil may be suitable for growing plants in, allowing colonists to grow their own food in giant greenhouses*

The right trajectory

Using current space technology, it takes about seven or eight months to reach Mars. You have to leave at just the right time, when the Earth is at what we call perihelion, or the closest point to the Sun, of the orbital path to Mars. Spacecraft to the Red Planet then use a special trajectory called a Hohmann transfer orbit. This works because of a law of orbital mechanics, which says that if you can increase the spacecraft's energy at perihelion, you can increase the aphelion of its orbit, which is how far it gets from the Sun. However, you also need to make sure you arrive in position in Mars' orbit around the Sun at the same time that Mars itself does. The alignment occurs only once every two years, meaning that if you miss it, you have a long wait for the next one.



Perihelion
This is Earth's closest point in the transfer orbit to the Sun. By launching at this time, it is possible to control the size of the spacecraft's orbit.

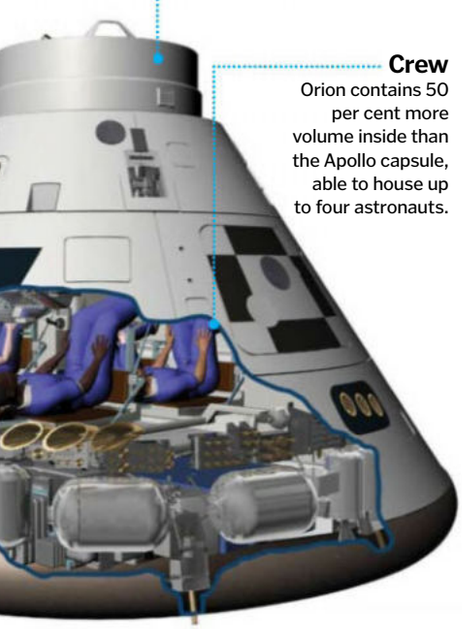
Transfer orbit
It takes seven to eight months to reach Mars via this orbit, which uses the minimum amount of fuel.

Entering orbit
The spacecraft must then fire a retro-rocket to slow down to allow capture by Mars' gravity, or by aerobraking in the planet's atmosphere, to enter orbit.

Aphelion
The spacecraft's most distant point in its orbit is at the same distance as Mars' orbit.

Mars
The spacecraft must cross Mars' orbit at exactly the same time and position as Mars itself.

Docking
Orion will have a docking system that will allow it to dock with the ISS and the habitation module.



Crew
Orion contains 50 per cent more volume inside than the Apollo capsule, able to house up to four astronauts.

Effects of long-term space travel

Staying fit and healthy during a long flight will be harder than actually getting there

Astronauts headed to Mars will face an uphill battle to stay healthy because space has lots of ways to make you poorly. Microgravity affects the blood circulation, causing bone loss and muscle atrophy, meaning the astronauts must constantly exercise to combat muscle wastage. While the gravity on Mars is just 38 per cent of Earth's gravity, many of these problems will be alleviated once the astronauts land. More deadly is radiation, from both the Sun and from cosmic rays coming from deep space. Because Mars does not have a magnetic field to deflect space radiation and keep it from the surface, astronauts will have to live inside shielded habitats. There is also the worry of psychological effects resulting from the strange environment and isolation from everyone on Earth.

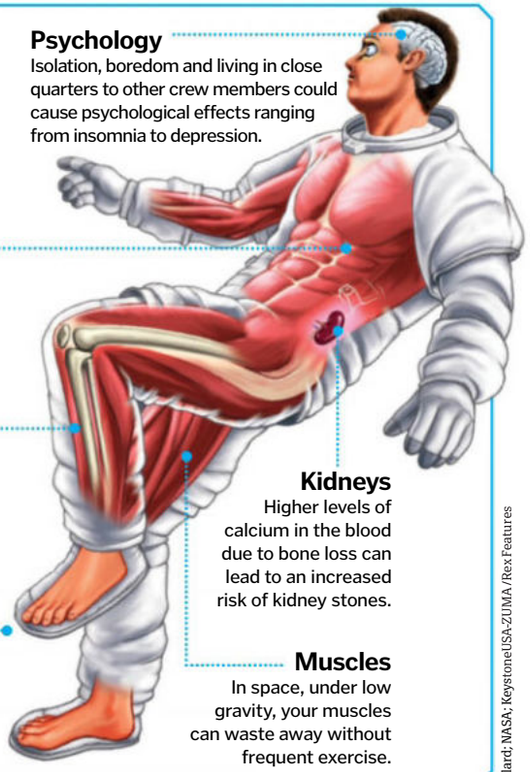
Radiation
Solar flares from the Sun and cosmic rays from deep space would expose astronauts to potentially deadly levels of radiation during a Mars mission.

Psychology
Isolation, boredom and living in close quarters to other crew members could cause psychological effects ranging from insomnia to depression.

Blood
Microgravity slows down your blood circulation, increasing blood pressure and heart rate.

Bones
In microgravity your bones are not required to support your body weight, so bone tissue is broken down much faster than it is replenished.

Balance
In the microgravity of space, as well as the reduced gravity on Mars, the human body will take time to adjust.



Kidneys
Higher levels of calcium in the blood due to bone loss can lead to an increased risk of kidney stones.

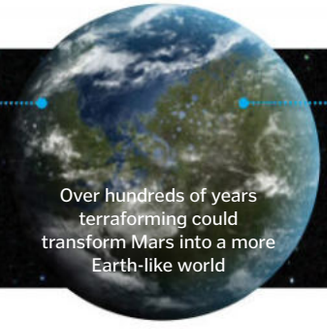
Muscles
In space, under low gravity, your muscles can waste away without frequent exercise.

2030s

The 2030s are probably the earliest that the space agencies of the world will launch a manned mission to Mars, although the Mars One project wants to do so in 2024.

2100s

Terraforming Mars will require the atmosphere to be thickened and warmed. This could be accomplished by releasing greenhouse gases from factories.



Over hundreds of years terraforming could transform Mars into a more Earth-like world

FAR FUTURE

After hundreds or even thousands of years, the atmosphere could grow thick enough for liquid water to survive on Mars' surface.

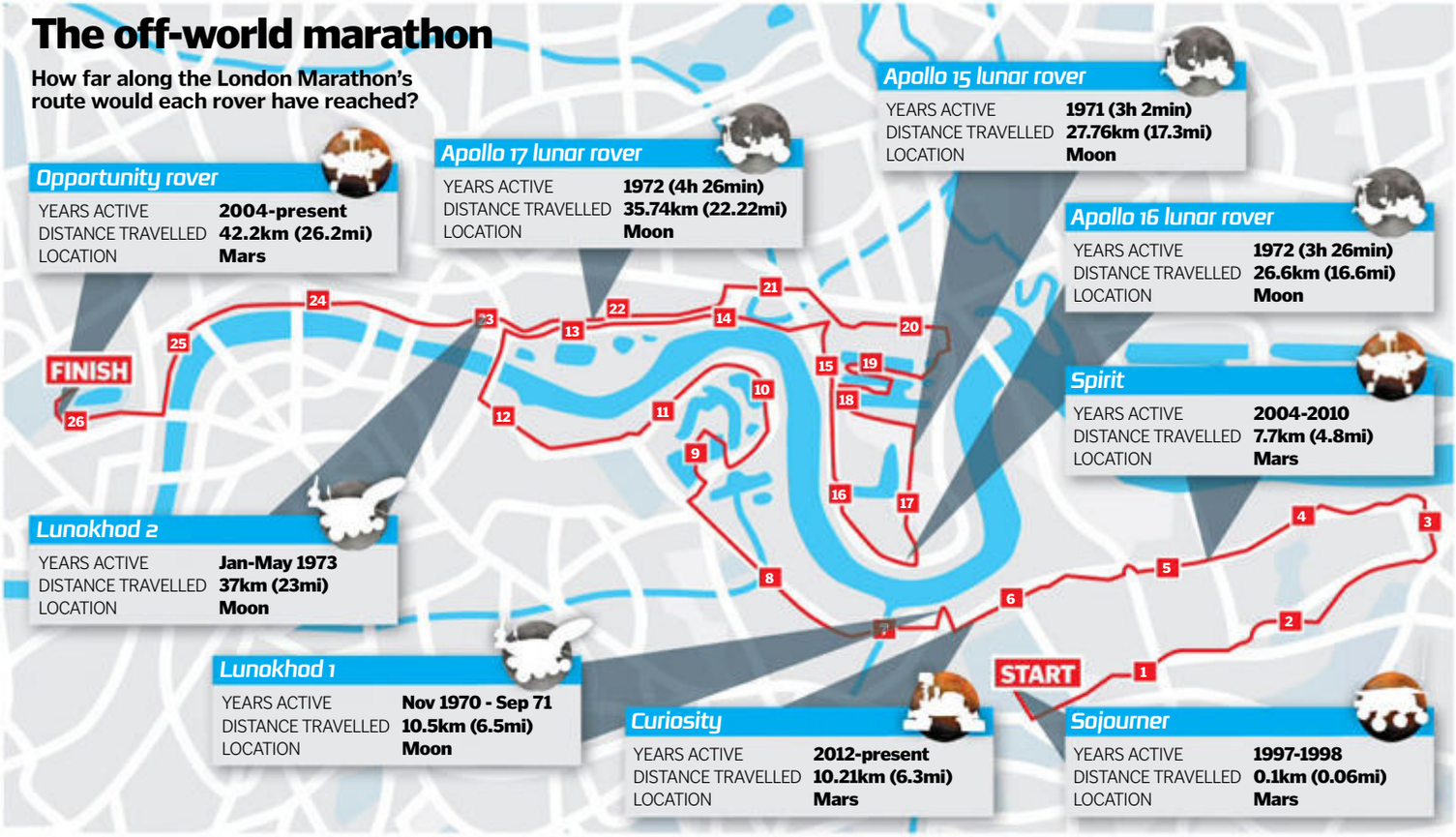
"Its mission was simply to photograph the planet and create an archive of hi-resolution, aerial images"

How far have we travelled on other worlds?

Our rovers have been busy breaking distance records on the Moon and Mars

The off-world marathon

How far along the London Marathon's route would each rover have reached?



How do Landsat satellites work?

Discover how and why this orbital space programme is taking photos of our home planet

In 1972, the very first in what would become a series of Earth-orbiting satellites in the Landsat programme was launched. Inspired by Apollo 17's famous 'Blue Marble' picture of Earth from space, Landsat's mission was simply to photograph the planet and create an archive of hi-resolution, aerial images that would prove a useful resource to people working in many different fields, including agriculture, forestry, geology, education, mapping, conservation and emergency response.

Landsat measures light reflected by Earth from the Sun. As different surfaces reflect various amounts of light, this tells us a lot about our planet's surface. The most recent satellite, Landsat 8, is capable of collecting images in multiple bands of visible and infrared light. It is tailored with two new spectral bands that can make specific observations of coastal regions and of high-altitude cirrus clouds, allowing scientists to take measurements of air and water quality. Landsat 8 takes 400 images a day and returns them to the United States Geological Survey (USGS).

The Landsat programme has recorded how the Earth has changed over the last 40 years from its lofty orbit

5 TOP FACTS
ROGUE PLANETS

No sunsets
1 Because rogue planets do not orbit a star, they have no sunrises or sunsets, or even seasons.

How to find them
2 Because they don't orbit a star, astronomers can't use the usual planet-finding methods. Instead they are spotted by their infrared light, or by how their gravity magnifies light of more distant stars.

A swarm of planets
3 Astronomers have found 13 rogue planets in the giant star-forming region of the Orion Nebula, which is visible to the naked eye in the night sky.

Finding a new home
4 Not all rogue planets are destined to wander alone. Research from astronomers at Harvard University indicates that billions of stars may have captured rogue planets.

Underground oceans
5 Even if a rogue planet has no atmosphere and its surface is icy, heat from radioactive elements deep underground could keep a liquid ocean beneath the ice, like on Jupiter's moon Europa.

DID YOU KNOW? *Astronomers think they have found a moon around a rogue planet, which would the first-ever 'exomoon' found*

Your guide to the lonely planets

Rogue planets are worlds without stars to orbit, but instead are lost in interstellar space

There are around 200 billion stars in our galaxy, but astronomers have estimated that there are 100,000 times more rogue planets than there are stars. What are these lonely planets like?

You might expect them to be cold and lifeless, but this is not necessarily the case. Some planets do not need a sun to stay warm. If their atmosphere is thick enough, coupled with heating from the decay of radioactive elements in the ground or from volcanoes, they could stay warm enough for liquid water and microbial life to exist. There is a good chance they might still be hanging onto the dense atmosphere of hydrogen and helium they were born with, because they do not have the stellar wind of a nearby star to blow the atmosphere away.

So what causes these worlds to become runaways? There are at least three ways. The first is that they could be born alone – some of the biggest gas giants are very similar to brown dwarfs, which are failed stars that form like stars, direct from a collapsing gas cloud. Another way is that a star that wanders too close to the black hole at the centre of the Milky Way could have its planet pulled away from it and sent hurtling through space and out of the galaxy at 48 million kilometres (30 million miles) per hour. Finally, planets can be kicked out of solar systems by larger planets migrating in their orbits. The migrating planet's gravity forces other, smaller worlds out of the planetary system. Some astronomers even think our Solar System once had five giant planets, but that one was ejected as the others migrated.

Beneath the clouds
Life could still exist on rogue planets, even without a star, if the atmosphere and radioactive decay keep the world warm enough.

Thick atmosphere
If a rogue planet has a thick atmosphere, it could help to retain warmth and preventing the world from freezing over, even in the dark depths of space.

Hypervelocity
The gravity of the black hole is able to throw the planet away at a tremendous speed, amounting to a few percent of the speed of light.

Lonely among many
It's thought that there are trillions of rogue planets lost in the galaxy, and many more have been ejected from the galaxy altogether.

Heat from the core
The core of a rogue planet can remain molten and radioactive elements in the rock can decay and potentially produce enough heat to maintain liquid oceans.

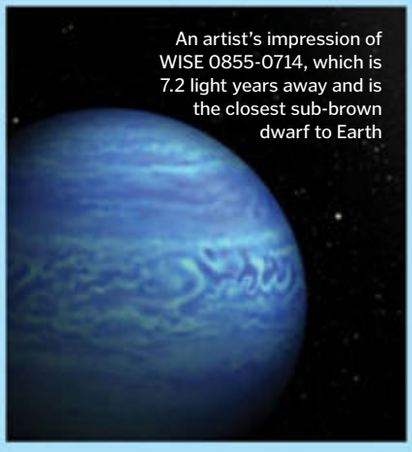
Black hole
When a star with a planet gets too close to the supermassive black hole in the Milky Way, it flings the planet away from its star.

Runaway worlds

Some rogue planets are in a real hurry, racing away from the Milky Way at 30 million miles per hour

Brown dwarfs: overgrown planets or failed stars?

Brown dwarfs are gas giants that are too small to become a star – they cannot reach the temperatures and pressures within their core to begin fusing hydrogen into helium. The smallest brown dwarfs are about 13 times the mass of Jupiter, and anything smaller should be a planet, but the dividing line is blurred. Some rogue planets have formed like a star or a brown dwarf, condensing out of a cloud of gas. Astronomers call these sub-brown dwarfs, and the closest one found so far is called WISE 0855-0714 and is about 7.5 light years away. Its mass is between three and ten times the mass of Jupiter. Astronomers have found many planets with the same mass orbiting stars. WISE 0855-0714 is a cold object, with temperatures between minus-13 to minus-48 degrees Celsius (8.6 and minus-54.4 degrees Fahrenheit).



An artist's impression of WISE 0855-0714, which is 7.2 light years away and is the closest sub-brown dwarf to Earth

"The mission will prove a number of the capabilities humans need to reach Mars"

Capturing asteroids

NASA's mission to redirect an asteroid into the Moon's orbit

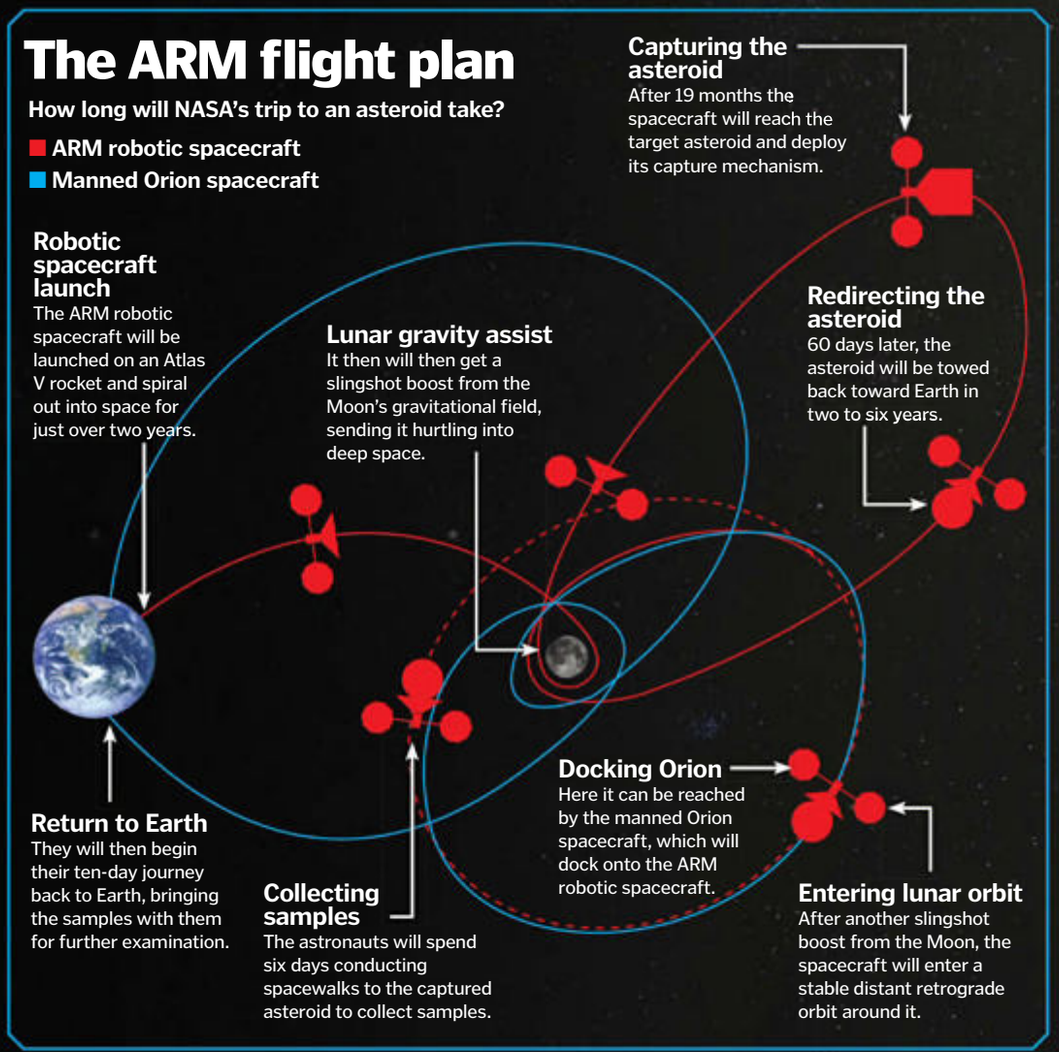
While the European Space Agency was busy with the Rosetta mission to land a probe on a comet, NASA has been developing its next space exploration plan. The Asteroid Redirect Mission (ARM) involves launching a robotic spacecraft in 2019 that will capture an asteroid and redirect it into the Moon's orbit. Astronauts will then visit it aboard an Orion spacecraft in the 2020s and collect samples that could hold clues to the origins of our Solar System and life on Earth. It is also hoped that the mission will prove a number of the capabilities humans will need to reach Mars, something NASA is hoping to achieve in the 2030s.

There are currently two concepts for the ARM robotic spacecraft, and NASA will choose the best one for the job in 2015. Along with citizen astronomers, it is also using telescopes to study the thousands of near-Earth asteroids and identify good candidates for both of the proposed spacecraft to collect. Although it is hoped the mission will also demonstrate techniques for defending Earth from impacts in the future, the asteroid chosen for the ARM mission won't pose any threat to us. It could remain in the Moon's orbit for hundreds of years and even if it did approach Earth, it would be so small that it would burn up in the atmosphere and disintegrate before reaching the surface.

The ARM flight plan

How long will NASA's trip to an asteroid take?

- ARM robotic spacecraft
- Manned Orion spacecraft



AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

An animation of the Asteroid Redirect Mission

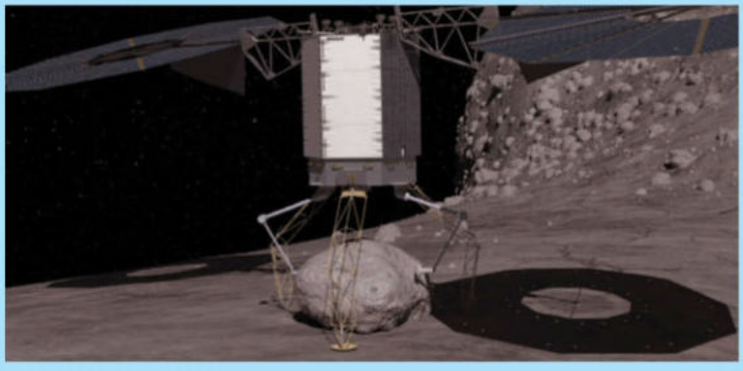
www.howitworksdaily.com

DID YOU KNOW? *Orion's journey to the asteroid in lunar orbit will be the farthest humans have ever travelled from Earth*

NASA could use an inflatable bag to capture an asteroid for examination in space by 2025

Learn more

Keep up to date with ARM by visiting **www.nasa.gov** and searching for the Asteroid Initiative. You can also get involved with the Asteroid Grand Challenge and help NASA hunt for potential asteroids to capture.



Robotic spacecraft concepts

The first of the two concepts for the ARM robotic spacecraft involves capturing a small asteroid in a 15-metre (50-foot)-long inflatable bag before towing it toward the Moon's orbit. The second uses robotic arms to retrieve a small boulder from the surface of a much larger asteroid.

Both concepts use advanced solar electric propulsion (SEP), an efficient way to move large payloads into deep space that could be crucial for getting humans to Mars. It involves using the craft's many solar panels to generate electricity, which is then used to ionise the atoms of propellant gas. Magnets are then used to push the ions out the back of the craft and repel them away to create thrust. Although the thrust is weaker than that produced by traditional rocket fuel, it can be sustained for longer to build up acceleration, making it ideal for long deep-space missions.

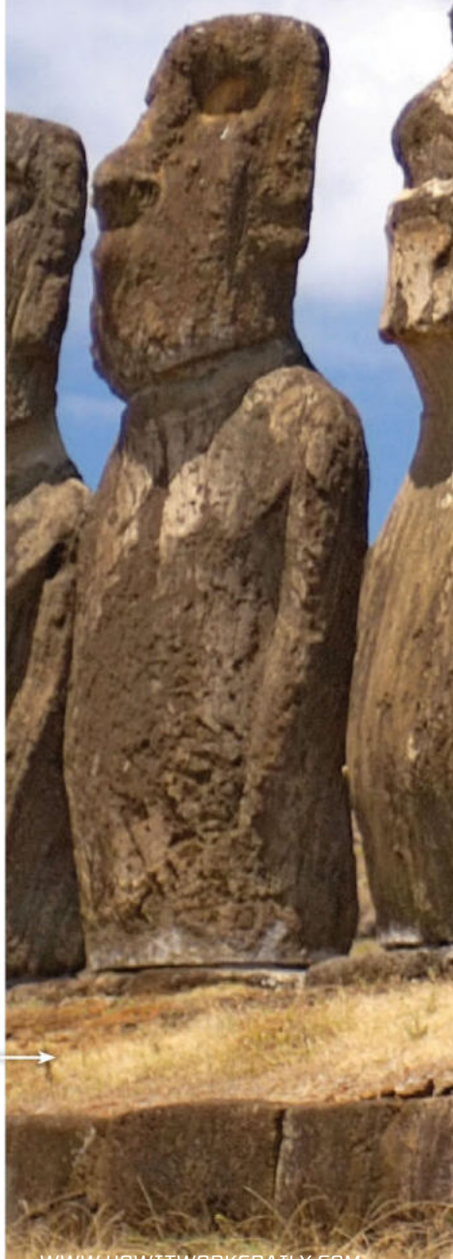
The mystery of Easter Island

Who built the giant heads of Rapa Nui and why?

The most easterly island in Polynesia, approximately 3,700 kilometres (2,300 miles) west of South America in the Pacific Ocean, Easter Island could hardly be more remote. Yet it's home to some of the most incredible man-made wonders on Earth – over 887 carved stone heads, called moai, that has seen the entire 166.3-square-kilometre (64.2-square-mile) island, known as Rapa Nui by its population, designated as a UNESCO World Heritage Site.

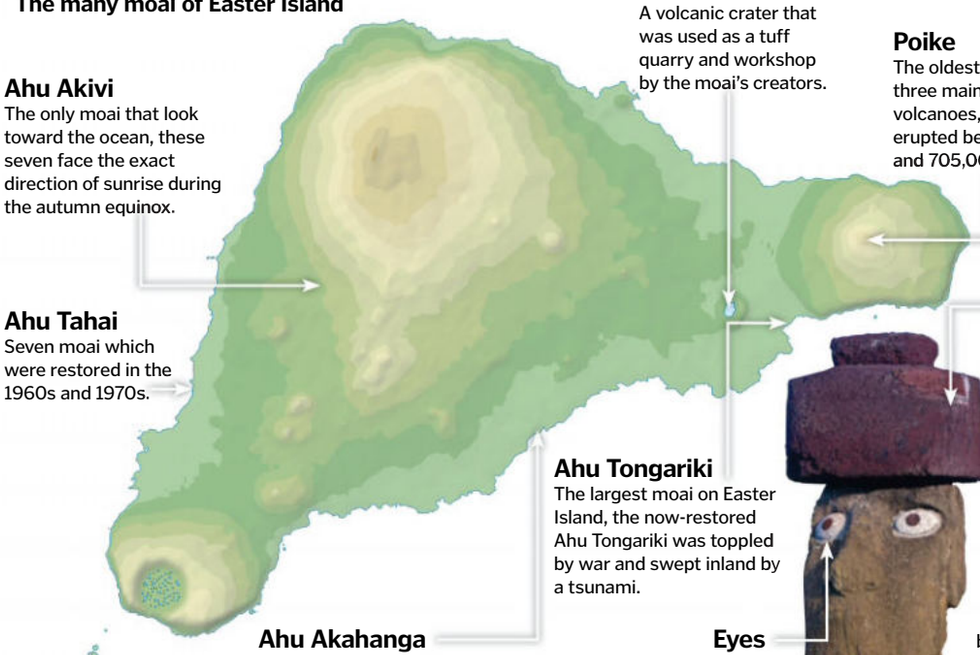
The origin of these stern-faced monoliths – which average four metres (13 feet) tall and weigh an average of 14 tons – and the society that built them is largely a mystery. What is known is that settlers travelling on wooden outrigger canoes arrived on the island between the 4th and 13th centuries and carved the moai sometime between the 10th and 16th centuries from tuff – a light, porous volcanic rock – and placed them upon platforms called ahu. Some even wear 'hats' of red scoria, representing the topknot hair styles of the Rapa Nui people. The eye sockets are believed to have held coral eyes with either black obsidian or red scoria pupils, while the bodies may have been carved with patterns that mimic the traditional tattoos of the Rapa Nui.

As for why they were carved, it may have been to honour important chieftains or warriors as some of them contained tombs in their ahu, or it may be to offer protection as with only a few exceptions they gaze over nearby villages. Ultimately it's impossible to know for certain. When Dutch explorers arrived on the island on Easter Day in 1722, the islanders that had created these breathtaking monuments had long since been divided by civil wars and many of its moai toppled, leaving only stories preserved in the oral histories of the Rapa Nui people and a forest of impassive stone heads breaking forth from the earth to stare out across the grass.



Treasure Island

The many moai of Easter Island



Rano Raraku
A volcanic crater that was used as a tuff quarry and workshop by the moai's creators.

Poike
The oldest of the island's three main inactive volcanoes, Poike last erupted between 230,000 and 705,000 years ago.

Ahu Akivi
The only moai that look toward the ocean, these seven face the exact direction of sunrise during the autumn equinox.

Ahu Tahai
Seven moai which were restored in the 1960s and 1970s.

Pukao
The stone cylinders that represent the figure's hair, carved from light-red scoria.

Ahu Tongariki
The largest moai on Easter Island, the now-restored Ahu Tongariki was toppled by war and swept inland by a tsunami.

Ahu
The stone platform at the base of the moai, sometimes used as a tomb.

Ahu Akahanga
Also known as 'the king's platform', these fallen moai are near the tomb of Hotu Matu'a, believed to be the island's first monarch.

Eyes
Gazing down at the nearest village, the eyes were usually made of white coral with black obsidian pupils.

THE STATS
MOAI FIGURES

NUMBER OF HEADS **887**

880 FACING INLAND

FACING THE SEA **7**

79 TAKEN OVERSEAS

TALLEST **10m (33ft)**

HEAVIEST **86 tons**

DID YOU KNOW? *Swiss author Erich von Däniken speculated the moai were built by aliens; the 'ancient astronaut' hypothesis*

What happened to their creators?

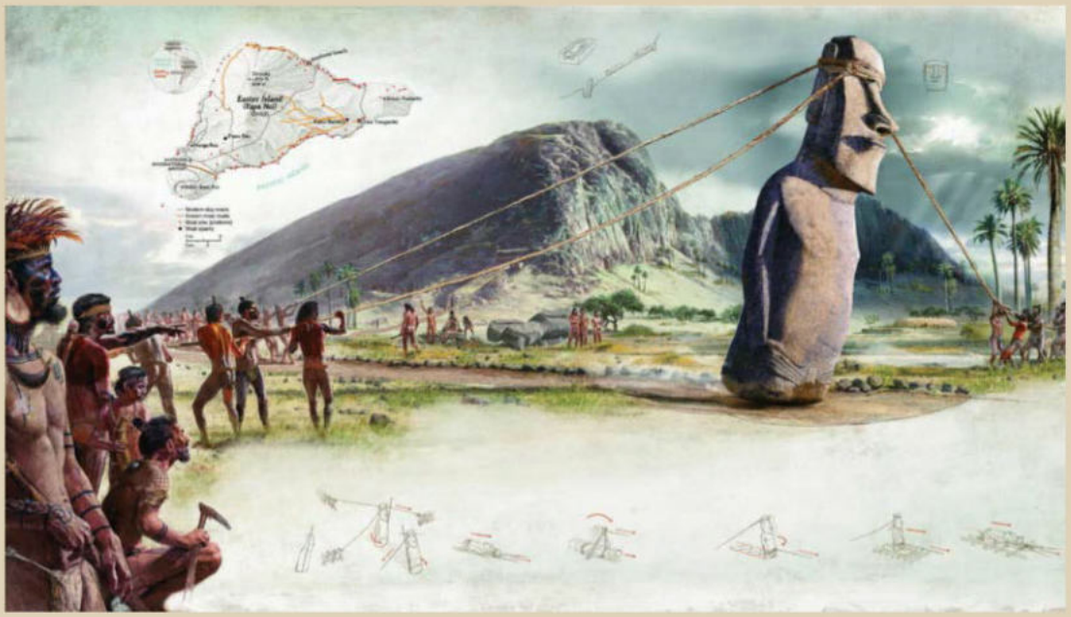
Though largely barren and sparsely inhabited by the time Europeans arrived on Rapa Nui, the island was once heavily forested and home to several now-extinct species of birds before it suffered a mysterious collapse. One theory is that the rats and chickens brought by the original settlers as a source of food laid waste to the island's limited plant life. When the last palm trees were cut down – maybe as late as the 17th century – the Rapa Nui's ability to build boats and fish for food was also restricted. As conflict between tribes for the dwindling resources became inevitable, the population plummeted and some even resorted to cannibalism.

How were they moved?

Though the carvings are impressive, getting them into place suggests a feat of engineering even more so. With no evidence of wheels or cranes – and no large animals to do all the heavy pulling – archaeologists originally believed the moai may have been moved on sledges or wooden rollers as far as 18 kilometres (11 miles) from the quarry.

Though some scholars still support this, a more recent theory is that the curved base of the moai was designed for them to be 'rocked' from side to side and then pulled forward by carefully coordinated teams of workers with ropes. Damage to the base during experiments moving replica statues is consistent with flakes of rock found along roadsides on the island.

The debate is still ongoing, but this theory may be the source of Rapa Nui folklore that recalls the statues being commanded to walk by the gods.



DID YOU KNOW? *In 2013 archaeologists discovered jars of wine in the ruins of a 3,700-year-old Canaanite palace cellar*

How wine was made in Ancient Israel

Thousands of grapes and a whole lot of manpower was needed to make the Israelites' favourite beverage

Israel's hot, sunny climate and mountainous landscape makes it the perfect place for growing grapes. In ancient times, it was situated along a wine-trading route, which brought winemaking knowledge and influence to the area. People would drink about a litre of wine a day, so knowing how to make lots of wine fast was a very good skill to have.

The ancient Israelites harvested the grapes at the height of summer, and then brought them to 'wine presses' cut into the rocky ground for fermentation. First, they were tipped into what was called a 'treading pool' where vineyard workers would tread on the grapes with their bare feet to crush them. The juice would then flow through a channel into a vat, where the fermentation process would take place.

The yeast on the skin of the grapes would react with the sugars in the juice and turn them into alcohol. Once fermentation was over, the wine would be collected in leather bags called wineskins or big jars called amphorae. These were often coated with resin, which helped to preserve the wine and gave it a woody flavour. Olive oil was then poured on top of the wine to prevent exposure to the air, and the jars were sealed with more resin or clay. The wine would be stored in cool, dark cellars for months or even years, and eventually sold in Israeli markets or exported to foreign lands.

An ancient wine press

Many of these have been excavated in Israel, which give us an idea as to how wine was made

Vat
Here the fermentation process would take place, with the juice bubbling away for several days.

Channel
The juice from the crushed grap through this channel into the fermentation vats.

Jars
Once the bubbling stopped, the wine was poured into clay jars like these and sealed with olive oil, clay or resin.

Rock
The limestone rock in Israel is perfect for wine presses, as it's easy to cut and holds liquid well.

Treading pool
The grapes were poured into a large pool, where they were crushed under foot.

Filter
Dried shrubbery or other plant fibres were used to filter the grape juice.

Why do some wines taste better with age?

Tannins are a group of molecules found in grape stems, skins and seeds that are produced by the grapevine to help defend against hungry critters. They make unripe grapes taste bitter, meaning that if animals or people try to eat one, they'll soon be put off. Tannins also bind to the proteins in your saliva that make it slimy, leaving your mouth feeling dry. When wine is first bottled, it will taste very bitter and very dry.

However, over time small amounts of oxygen leak through the cap and react with the tannins. This changes their molecular structure and means that they will no longer bind to the salivary proteins. Instead, they will linger pleasantly on your gums, cheeks and tongue. As the wine ages, it also becomes much less bitter. The older the wine, the richer and more complex it becomes. But beware – leave it too long and its fruitiness will disappear completely!

Tannins also affect the colour of wine. The older they are, the deeper the colour

"As each pig came with a different-sized bladder, original rugby balls came in a variety of sizes"

How record players work

The science behind the recent vinyl revival has been sound since 1877

The technology of record players is all based on sound vibrations recorded physically into grooves of a vinyl disc. The delicate needle, or stylus, reads these vibrations as the record rotates, translating them into sound through the arm of the player.

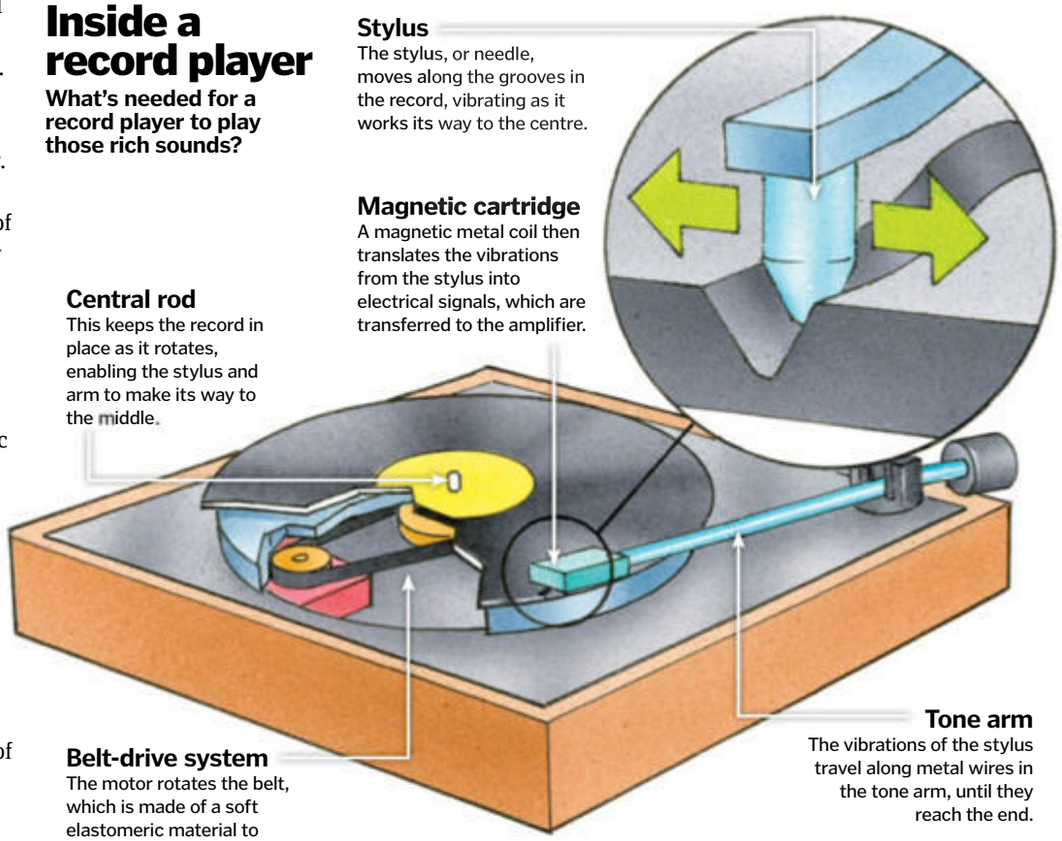
Thomas Edison's phonograph, invented in 1877, was the earliest example of this method of recording and reproducing sound, paving way for Emile Berliner's gramophone. This was the first machine to use flat disc records, initially made of rubber, which could be rotated and played on the device using a hand crank.

Though records were subsequently made from shellac, then polyvinyl chloride, the basic principles remained the same. The turntable, the main component of the player, rotates the vinyl with either a belt-drive or direct-drive system, reducing the noise of the motor as much as possible.

However, the delicate etchings of the vinyl itself are where the music is all happening. These form a gradual spiral in toward the centre, which the stylus follows as the record turns, all the while picking up the thousands of miniscule bumps and translating them into good vibrations. So, the next time you put on a Kool and the Gang record, you'll quite literally be hearing something groovy.

Inside a record player

What's needed for a record player to play those rich sounds?



Stylus
The stylus, or needle, moves along the grooves in the record, vibrating as it works its way to the centre.

Magnetic cartridge
A magnetic metal coil then translates the vibrations from the stylus into electrical signals, which are transferred to the amplifier.

Central rod
This keeps the record in place as it rotates, enabling the stylus and arm to make its way to the middle.

Belt-drive system
The motor rotates the belt, which is made of a soft elastomeric material to reduce interference.

Tone arm
The vibrations of the stylus travel along metal wires in the tone arm, until they reach the end.

The original rugby balls

The grisly roots of the game, not suitable for vegetarians

Produced close to the school from which its name derives, the rugby ball was originally made from pigs' bladders, which is why they have such an unconventional shape. In the 19th century, shoemakers Richard Lindon and William Gilbert began making balls for the pupils at Rugby School by blowing up the bladders and encasing them in stitched leather. The bladders were even inflated manually – a clearly unpleasant task.

As each pig came with a different-sized bladder, practically this meant the original rugby balls came in a variety of sizes, but the characteristic oval shape only emerged later. It wasn't even until 1845 that rugby rules, written by the pupils of the school, were established. By 1892, specifications for the ball were written into the game, stating among other things that it be hand-sewn with eight stitches per inch and have a weight of 368.5 grams (13 ounces).

Originally, rugby balls were less oval and more rounded in their shape

© Alamy; Thinkstock

Who were thought to have lived in Chaco Canyon?

A Babylonians **B** Aztecs **C** Navajo

Answer:
When US Army Lieutenant James Simpson first explored the Chaco Canyon and its elaborate ruins in 1849, he believed it meant the famous Aztec Empire had once expanded as far north as New Mexico. He turned out to be ever-so-slightly wrong.

DID YOU KNOW? *Many modern Native American tribes claim descent from the Anasazi*

Anasazi cliff dwellings

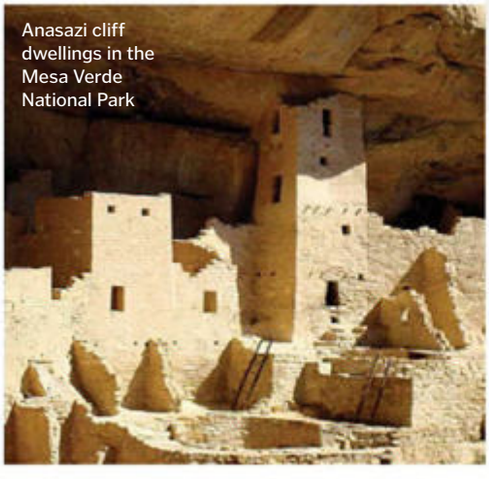
Who built these incredible cave cities in the Colorado desert?

When European Americans first explored Chaco Canyon in New Mexico in 1849 they must have thought they'd found a mythical lost city. Against the canyon wall were the ruins of vast five-storey homes, a warren of around 800 rooms like an entire town within a single set of walls. Among the debris were ceramic cylinders and broken pottery, evidence of dams and irrigation trenches that diverted water, and a network of roads nine metres (30 feet) wide.

The Anasazi, whose name comes from the Navajo word for 'ancient enemies' or 'ancient ones', built numerous similar settlements across the Four Corners region at the intersection of what is Utah, New Mexico, Arizona and Colorado today, from as early as the 10th century.

Then at some point before the end of the 13th century, this mysterious culture suddenly moved from their multi-storey 'great houses' and into caves that had been carved into the seemingly inaccessible orange-brown cliff-faces of southern Colorado. Just as ambitious as their original homes, these cliff dwellings had several rooms connected by ladders and walls of sandstone blocks. By the 14th century these new dwellings were empty too; the reason for the Anasazi's sudden migration may also be responsible for their sudden disappearance.

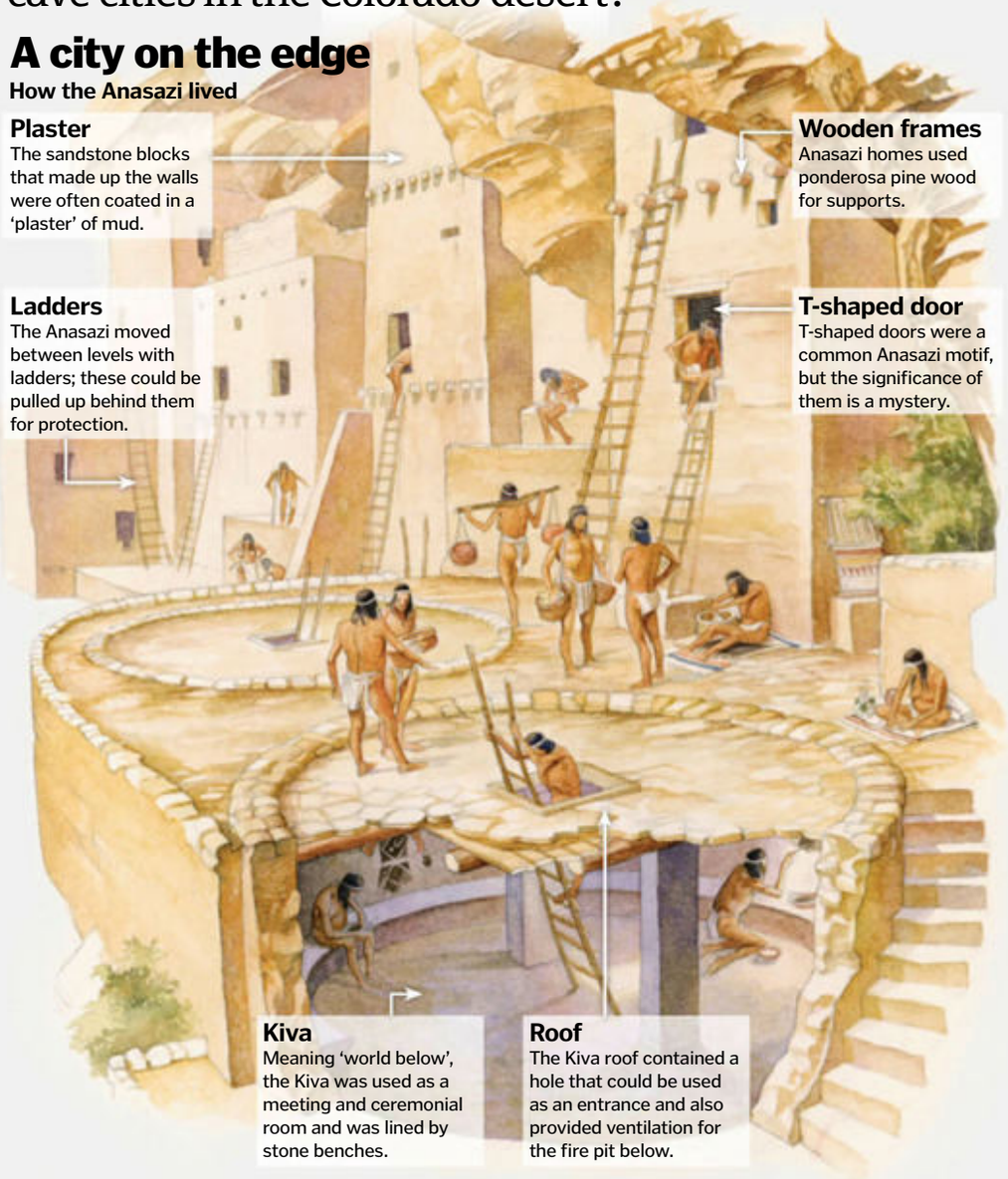
Facing competition from other tribes over dwindling water supplies, the Anasazi may have gathered their scattered communities into more defensible positions – literally with their backs to the wall. From there they may have left, heading further south in search of swollen rivers or plentiful rainfall well away from the arid cliffs and canyons of the Colorado desert.



Anasazi cliff dwellings in the Mesa Verde National Park

A city on the edge

How the Anasazi lived



Plaster
The sandstone blocks that made up the walls were often coated in a 'plaster' of mud.

Wooden frames
Anasazi homes used ponderosa pine wood for supports.

Ladders
The Anasazi moved between levels with ladders; these could be pulled up behind them for protection.

T-shaped door
T-shaped doors were a common Anasazi motif, but the significance of them is a mystery.

Kiva
Meaning 'world below', the Kiva was used as a meeting and ceremonial room and was lined by stone benches.

Roof
The Kiva roof contained a hole that could be used as an entrance and also provided ventilation for the fire pit below.

Anasazi riches

Though the Anasazi cities and cliff dwellings are confined to a relatively small area, this ancient Native American culture had a network of trade that stretched as far west as the Californian coastline and as far south as Mexico. Thanks to their valuable mines, the Anasazi were able to import goods as diverse and luxurious as parrots, seashells and copper bells from the Gulf of Mexico in exchange for turquoise, which was used in jewellery and mosaics. Relics and funeral masks made from glistening green Anasazi turquoise have been found as far away as the Mayan city of Chichen Itza, taking pride of place in the elaborate tombs of Mexico's Yucatán Peninsula.

An Anasazi turquoise pendant

BRAIN DUMP

Because enquiring minds need to know...

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MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in zoology from Oxford Uni and another in real-time computing. He builds steampunk gizmos and electronic gadgets, and his articles about science, tech and nature have been published around the world.

Laura Mears

Laura studied biomedical science at King's College London and has a masters from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

Having earned degrees from the University of Nottingham as well as Imperial College, Alex has worked at many a prestigious institution around the world, including CERN, London's Science Museum and the Institute of Physics.

Sarah Bankes

Sarah has a degree in English and has been a writer and editor for more than a decade. Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

Shanna Freeman

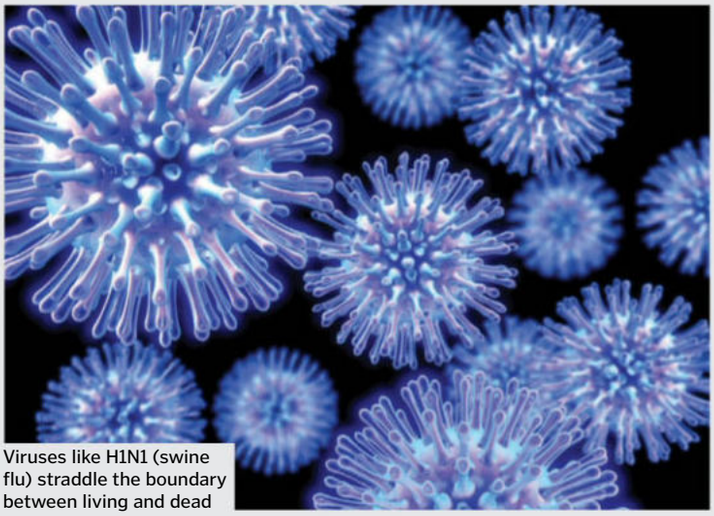
Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!

Some grass in large stadiums is imported from somewhere else

Where do they grow the grass for the world's sports stadiums?

Anthony Flooks

Grass for sports stadiums can either grow from seeds that are planted in situ, or be ordered and laid from turf companies. The process isn't as straightforward as you might imagine, though – it is essential the right grass or mixture of grasses be used, depending on the climate and the sport that will be played upon it. There are two main types of grass, cool-season and warm-season, which have many varieties. Seeds must be planted in a certain way and at the right time of year, and the ground must have been sufficiently prepared prior to this. Care and maintenance is then key to successful growth. **SB**



Viruses like H1N1 (swine flu) straddle the boundary between living and dead

Are viruses dead or alive?

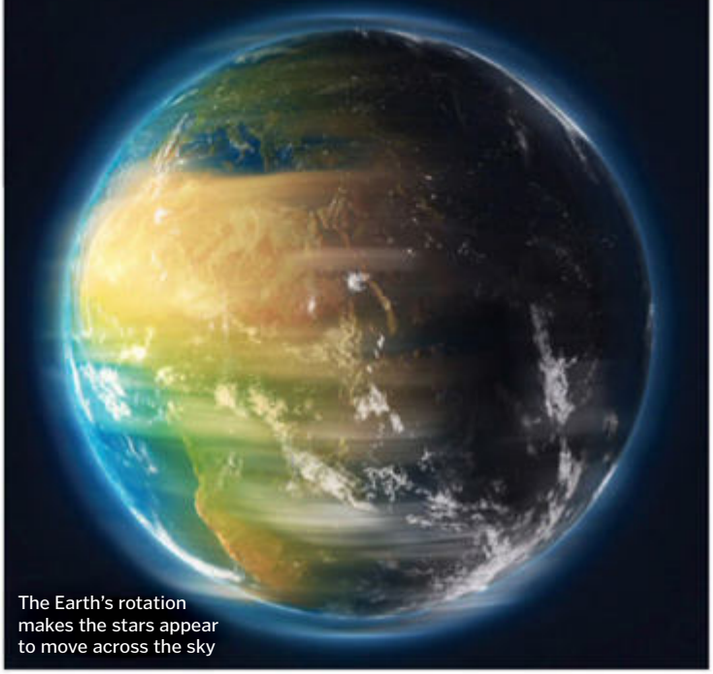
Patricia Robertson

Viruses can be seen as either alive or dead depending on the chosen definition of life, but most scientists see them as somewhere between the two. Viruses are essentially nucleic acids (RNA or DNA) encased in protein, but they share several characteristics with living organisms. They have genetic information, which they pass on to future generations, and they can react to their environment. Once they have infected another organism, they produce copies of themselves by hijacking the host cells. Yet unlike living organisms, viruses cannot survive on their own: without a host to infect they remain dormant, incapable of reproducing. **AC**

Why can't we feel the Earth spinning?

Caroline Windsor

You can! The Earth's rotation generates a centrifugal force pulling upward, acting to partially balance out the force of gravity pulling us down, but it's very subtle. At the equator, you weigh 0.346 per cent less than at the poles. That's a difference of only about 250g (8.8oz). The Earth's rotation also causes the Coriolis effect, which deflects the wind in opposite directions in the northern and southern hemispheres. Westerly or southwesterly winds in Britain are due to the Coriolis effect, so you could say you feel the Earth spinning when the wind in your face is from the west or southwest. **LV**



The Earth's rotation makes the stars appear to move across the sky

Why do we have blood types?

Fred Croft

The short answer is that we still don't know. There an incredible 33 different blood-group systems in humans, but the most commonly talked about is the A, B, O system, which has four types. Depending on your genetics, your red blood cells are coated in A antigens, B antigens, both A and B antigens, or neither (in which case you are blood type O). We know these factors affect blood transfusion, but the real reason behind different blood types seems to be related to the spread of infection; for example, people with blood type O are more susceptible to bubonic plague, but are better protected against malaria. **LM**

Covering up in cold weather helps to combat dry skin

Why does cold weather give you dry skin?

Emma Hughes

Many of us suffer from dry skin in colder weather, and it all stems from lower humidity, or a lower level of moisture in the air. Cold outdoor air is dry, and winter winds can cause skin to chap and dry out as well. Then once we go inside, our skin is subjected to more dry air in the form of heating – central heating, fireplaces, wood-burning stoves all contribute to it. We may also find ourselves taking hotter and longer showers and baths in winter to warm up, but we're once again drying out our skin. Covering up when outside, using humidifiers and frequent moisturising can help combat the problem. **SF**

Why does unhealthy food taste better than healthy food?

Simon Gale

We are born biologically programmed to like sweet, fatty foods; it is an evolutionary hangover dating back to our early primate ancestors. In the past, the desire to eat high-calorie food would have been critical for our survival, driving us to seek out foods that would have provided a lot of energy, such as ripe fruit, nuts and honey. They were harder to find, but when eating these foods we are rewarded with a hit of the feel-good neurotransmitter dopamine, encouraging us to find more. In modern society these foods are now easy to come by, and we have managed to intensify the feel-good rewards by creating recipes with added sugar and fat, massively magnifying the pleasure we get from eating. **LM**

Sugary foods activate the reward pathway in your brain, making you feel good

FASCINATING FACTS

The first selfie is 176 years old

The first photographic self-portrait was taken by American photography pioneer Robert Cornelius in 1839. However, the first time one was referred to online as a 'selfie' was in 2002 on an Australian web forum.

A selfie is typically taken on a smartphone or tablet

BRAIN DUMP

How does acupuncture work?

Megan Rose

Whether acupuncture really works is a matter still debated in medical and scientific communities. This is because designing medical trials to test acupuncture is challenging. A good trial would pit the treatment against a harmless placebo, and neither the patients nor the doctors would be aware of which they were receiving or administering. With acupuncture, this is near impossible.

In order to get around this, the trials use 'sham acupuncture', either inserting the needles in nontraditional places, or pretending to insert them while in reality just holding the needles against the skin. In these tests, acupuncture was found to be more effective than the sham and the placebo for relieving pain associated with headaches, osteoarthritis, back and neck pain, but for other conditions such as rheumatoid arthritis, and shoulder pain, there was no convincing evidence that it works. One idea is that it might stimulate the production of endorphins, the body's natural painkillers. **LM**

Why do we get dark circles under our eyes when tired?

William Tucker

Fatigue isn't the only reason for dark circles forming under our eyes, but it is a very common one. The skin under our eyes is very thin, and the dark colour is due to the veins just underneath the skin. It's thought the veins are more prominent when we're tired because the body has to produce more of the hormone cortisol to keep us alert. Cortisol actually increases blood volume, enlarging the blood vessels and making them stand out more, becoming more easily visible. Genetics and age also play a part; skin thins as we age, which is why some elderly people appear to have perpetual dark circles. **SF**

Red light rays reach us at sunset, while other colours are dispersed

Why is the sunset red?

Geoff Stokes

The electromagnetic radiation given off by the Sun contains a wide spectrum of wavelengths, and human eyes are sensitive only to certain parts of it. The colours we see depend not only on what our eyes are sensitive to, but also on what has happened to the light before it has reached us and how the Sun is reflecting it, because different colours are associated with different wavelengths. When the Sun sets, its position in the sky is low compared to where it sits in the middle of the day. Therefore, the light emitted has to take a different path. Its longer journey through the atmosphere means the colours with shorter wavelengths, such as blues and greens, are scattered and dispersed by the atmosphere, leaving mostly reddish components of light (those with longer wavelengths) to reach our eyes. **SB**

FASCINATING FACTS

Human brains are not the world's biggest

An adult human brain is 1.3-1.4kg (2.8–3lb). That's actually slightly smaller than a bottlenose dolphin's brain, but dolphins are heavier than us. So proportionally, our brains are larger than theirs.

Ancient Egyptians used make-up

Ancient Egyptians used make-up such as lipstick and a sort of eyeliner called kohl. The former used ground carmine beetles for colour and the latter was a mixture of ash, burnt almonds, lead and other metals.

Humans are very salty

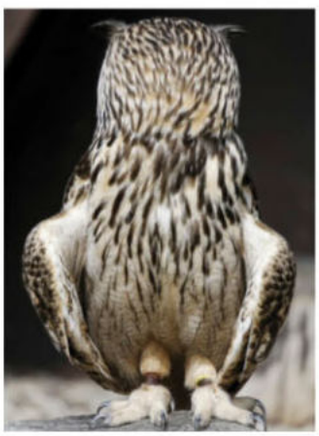
The concentration of sodium in the human body is around 135-145mEq/L, which works out at around 0.15 per cent of your bodyweight. For a 70-kilogram (154-pound) adult, that would be around 100 grams (3.5 ounces).

Why do the planets rotate around the Sun?

Grant Hawth

The planets were set in motion during the formation of our Solar System and are held in orbit by the Sun's gravity. About 4.6 billion years ago, our Solar System was a huge cloud of dust and gas, rotating as it collapsed. As it spun it flattened out, forming the Sun at its centre and a disc of matter surrounding it. Particles of dust in this disc collided and accumulated to form planets. Without the Sun, these planets would travel off into space in a straight line, but the star's immense gravity curves their paths into orbits. **AC**

Since the Solar System formed, its material has rotated around the Sun



How far can an owl's head turn?

Amy Parker

An owl can swivel its head 270 degrees in either direction. Some scientists have claimed this is due to bone and vascular structures that run along its neck to the skull. It is these structures, rather than the fact an owl has double the number of bones in its neck compared to a human, that enable it to turn its head that far. Its head is also only connected by one socket pivot, making it more flexible than ours, which is connected by two. The reason an owl does this is because it has fixed eye sockets and therefore poor peripheral vision. **SB**

Why do some animals have whiskers?

Gemma Lawrence

Whiskers act primarily as sensory tools, helping their owners to collect information about their immediate environment. Also known as vibrissae, these long, stiff modified hairs grow around the nostrils, lips and eyes of almost all mammals, and sometimes also on their paws. Dense packets of nerves at the base of each whisker feed into a specific pathway, picking up tiny vibrations. Animals can sense objects as well as air currents thanks to their whiskers, alerting them to approaching dangers, particularly in the dark. Different species use their whiskers for slightly different purposes. Many predators, such as seals or shrews, use theirs to detect prey. Rats can move their whiskers rapidly, scanning their surroundings to build up mental maps. Cats use them to judge whether a narrow space is wide enough for them to squeeze through. Whiskers can also allow fulfil a social function – for example, dogs show fear by flaring out their whiskers. **AC**

How is blood pressure measured?

Rory Bennett

The most common method for measuring blood pressure uses a so-called sphygmomanometer. This is an inflatable armband with a pressure gauge and small hand pump. The doctor pumps the armband up enough to temporarily squeeze the brachial artery in your arm shut. They then gently let a little air out and listen with a stethoscope at the crook of your elbow, until they hear the blood just start to flow again. The pressure reading at this moment is your systolic pressure, which is the maximum pressure during each heartbeat. Releasing more air until there is no more sound through the stethoscope, gives the minimum pressure for the heartbeat, which is the diastolic pressure. **LV**

Blood pressure is expressed as systolic pressure over diastolic pressure

BRAIN DUMP

Geysers are extremely rare. There are only about 1,000 on the planet

Why do geysers spurt out hot water?

Flora Holt

A geyser is a natural vent in the Earth's surface, which intermittently spurts out tall columns of hot water and steam. They form in areas that have volcanic activity. What makes a geyser such a unique and incredible phenomenon is that it requires at least three very specific conditions to form: a water supply that refills the geyser after an eruption; a heat source, which is normally hot rocks that heat the water; and a pressure-tight plumbing system to store the water as it is heated. As more hot water flows through the narrow pipes of the plumbing system, intense pressure causes it to erupt. **SB**

FASCINATING FACTS

Titov was history's youngest astronaut

The youngest person in space was Gherman Titov, a 25-year-old Russian cosmonaut who spent 25 hours orbiting the Earth on the Vostok 2 spacecraft in 1961.

Why do medications have side effects?

Jane West

The human body is an extremely complicated system; you cannot target one component without having knock-on effects elsewhere. Even seemingly innocuous substances such as sugar and water can cause damage if given in too high a dose. Pharmacologists try to balance the side effects with the benefits by comparing the safe blood concentration of a drug with the toxic concentration, a measure known as the therapeutic index. For medications that will be taken by otherwise healthy individuals, such as vaccinations, the side effects must be extremely mild, but for drugs that target life-threatening conditions like cancer, more severe side effects are allowed because the benefits outweigh the harm. **LM**

What's the difference between an alligator and a crocodile?

Ian Stalker

Alligators are crocodiles, but not all crocodiles are alligators. That's because both reptiles belong to the order Crocodilia. Both prefer swamps and slow-moving rivers, but alligators live mostly in freshwater in China and the southeastern United States. Crocodiles live in Africa, Asia, Australia, North America and South America, but they have a higher tolerance for salt water. They also have dot-like pits all over their skin that are used to locate prey via changes in water pressure, but alligators only have these dots on their jaws. Alligators generally have U-shaped snouts and their lower jaws are smaller than the upper, while crocodiles have V-shaped snouts and protruding teeth even when their jaws are closed. **SF**

How do we know dark matter exists if we can't see it?

Ian Surrey

Nobody has seen dark matter, but astronomers can detect its presence from the gravitational pull it exerts on other objects, such as stars or galaxies. Dark matter has mass but does not emit or absorb electromagnetic radiation, so it is invisible to telescopes. But the movements of distant galaxies suggest that something with a very large mass is altering their paths by exerting a gravitational force on them. We know relatively little about dark matter, but some believe it could be made up of a new type of subatomic particle called a WIMP (weakly interacting massive particle), although no experiment has yet proven that these exist. **AC**

How much tuna would I need to eat before I got mercury poisoning?

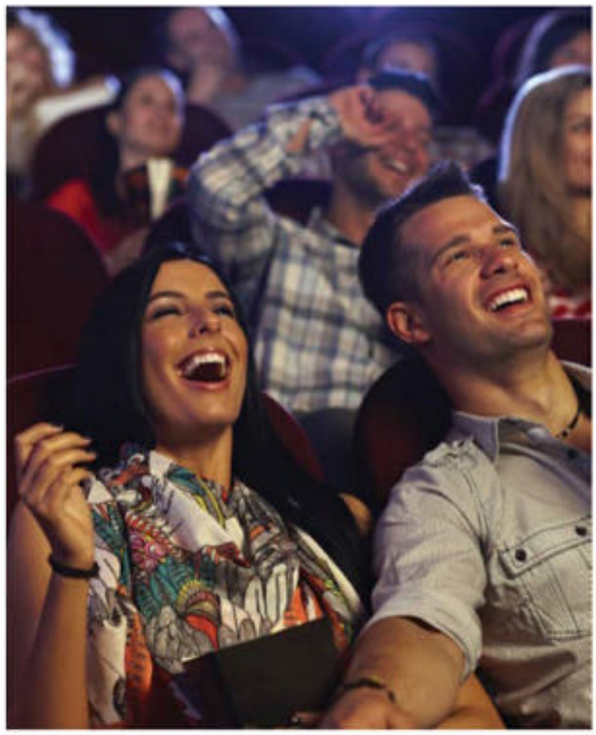
Ross Hamilton

Even if you eat it every day, you won't suffer acute mercury poisoning. The normal mercury levels in your blood are between one and eight parts per billion (ppb) and the toxic level is above 200ppb. Mercury in the environment comes mainly from volcanoes and pollution from burning coal. Tuna fish have high levels of mercury because they eat the fish that eat the plankton that absorb mercury from the seawater, and each animal in the food chain accumulates about ten times the mercury of the species it eats. If your diet consists mainly of fish, your own mercury levels could rise as high as 25ppb, which is still well below the toxic level. But the recommended level is less than ten ppb because mercury has subtle long-term effects, such as slower brain development in children. NHS guidelines say that pregnant women should only have two portions of oily fish or four cans of tuna per week. **LV**

Why is laughter contagious?

Nora Willis

We've long known that the sound of laughter makes us more likely to laugh ourselves – or at least smile, even if a joke isn't particularly funny to us. Numerous researchers over the decades have tried to find out exactly why, and it appears that we actually have a laugh generator in our brains. The sound of laughter has been found to activate the premotor cortical region, an area of the brain responsible for getting our facial muscles ready to react. Unpleasant sounds also activate the region, but we're still more likely to smile or laugh at the sound of laughter than, say, make a disgusted face if we hear an unpleasant noise. That's because laughter isn't just about humour; it's also a social tool that we use to fit in with other groups of people. Some scientists even theorise that our ancestors may have laughed together before they could speak. **SF**



Changing the clocks helped save fuel and money during WWI

Why do we change the clocks every year?

Harriet Firth

It was originally suggested in Britain by William Willett in 1907, to avoid wasting the daylight during the summer when the Sun normally rises long before anyone gets out of bed. The idea wasn't tried until 1916, a year after Willett's death. By that time Britain was at war and lighter evenings allowed the government to save fuel and money on lighting. At various times in the 20th century, Britain has experimented with double summer time, and staying one hour ahead of GMT all year. Lighter evenings in summer result in fewer road accidents overall, but winter mornings would be very dark if we didn't move the clocks back again. **LV**

New Brain Dump is here!

Don't miss issue 23 of **Brain Dump**, the digital sister magazine to **How It Works**, when it lands on the virtual newsstand on 1 April. You'll discover why flowers are different colours, why our hair turns grey, how self-raising flour works and more. There are also answers to curious questions like: why do whales eat krill and how do we balance?

Every issue is packed with stunning images and fun facts to entertain your friends and family with. Download the new issue of **Brain Dump** on the first day of every month from iTunes or Google Play. If you have a burning question, you can ask at **www.facebook.com/BraindumpMag** or Twitter – the handle is **@BrainDumpMag**.

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Gaming accessories

Up your game with these awesome add-ons

Playing videogames with your friends is great fun, but there are plenty of ways to power up your favourite games. Whether you're playing on a console or on your desktop computer, there are loads of accessories you can buy to up your game. These brilliant add-ons will power up your game and help you take your gaming to the next level.

1 Expanded storage

LaCie Porsche Design Mobile Drive 1TB
£69.99 / $109.99
www.lacie.com
Hard drives that are built into consoles and PCs fill up quite fast when you install a lot of games, so expanding your storage space is not a bad idea. Made to do exactly that, this external hard drive from LaCie is small, looks fantastic and offers plenty of storage for a good price.
Verdict: ●●●●○

2 Ultimate sound

Turtle Beach Stealth 500X
£199.99 / $229.95
www.turtlebeach.com
These headphones are totally wireless, and provide a 7.1 surround sound experience that's customisable with built-in presets. It's really comfortable even during longer gaming sessions, the adjustable microphone is really easy to manoeuvre and the audio quality is really great. This is a fantastic headset.
Verdict: ●●●●●

3 Use any controller

Cronus Max
£36.00 / $58.99
shop.controllermax.com
This handy device lets you play with any controller on any console. So if your friend has an Xbox One, but you love the PS3 controller too much to want to give it up, plug this in and you're good to go. You can even add features like rapidfire and quickscope to your controller with this brilliant add-on.
Verdict: ●●●●●

4 Take control

Logitech Wireless Keyboard K400
£39.99 / TBA
www.logitech.com
This connects to your Xbox or PlayStation via a Bluetooth dongle, so you can type to your heart's content. Unfortunately, unlike its more feature-packed big brother, the Harmony Smart Keyboard, it only lets you type and navigate menus, making game control impossible. Combined with a poor build quality, this is one to miss.
Verdict: ●●○○○

Checklist

- ✔ Recording device
- ✔ Controller adapter
- ✔ Hard drive
- ✔ Wireless keyboard
- ✔ Headset

EXTRAS Get inspiration for your experiments

BOOK

Replay: The History Of Videogames

Price: £12.99 / $17.44
Get it from:
www.amazon.com
If you're interested in the history of the videogames industry, this is the ideal starting point. Packed with interesting facts and interviews with industry insiders, this is an essential read, whether you grew up with a NES or the PS3 was your first console.

APP

SmartGlass

Price: Free
Get it from:
App Store
If you own an Xbox 360 or Xbox One, your smartphone or tablet can also act as a brilliant accessory. Grab the free SmartGlass app and you can use it to completely control your console. You can even choose channels while watching TV through the console as well as buy games.

WEBSITE

gamesTM

gamesTM.co.uk
If you want the latest gaming news and features, **gamesTM** brings you exclusive interviews, reviews and news for every console and hand-held device. Plus, if you want even more great features and hardware reviews, grab the **gamesTM** magazine.

Build quality
The whole keyboard feels a little flimsy when it's sitting on your lap.

Quick and easy
With a couple of cables and a well-designed app, you're ready to go.

Plug and play
You can use any controller – or even a keyboard and mouse – on any console.

5 Record highlights

Elgato Game Capture HD60
£139.95 / $179.95
www.amazon.co.uk
This simple tool hooks up between your console and television using an HDMI cable, and with a free piece of software you can record all of your gameplay footage in 1080p. It's easy to use and perfect for uploading your stuff to YouTube, or just saving your best moments to your computer.
Verdict: ✪✪✪✪✪

GROUP TEST

Putting products through their paces

The best fitness tracker bands

Check out the latest in wearable tech and find a fitness tracker that will suit your lifestyle

Versatile style
You can clip the Flash onto your clothing or secure it around your wrist to track your progress.

1 Misfit Flash

Price: £39.95 / $49.99
Get it from: www.amazon.co.uk / www.misfit.com

The affordable Misfit Flash is a good option for those sticking to a tight budget. The circular tracker can be worn on a clip or fastened around the wrist, which we found to be a little more reliable and secure when working out.

Although there's no built-in display, data can be reviewed on the compatible app, which is quick to set up and easy to use. Once synced with your smartphone, you can monitor your step count, calories burnt and distance covered, as well as set or review fitness goals and track sleep. Like the other trackers on test, there's third-party app support, which is useful if you're already using apps such as MapMyFitness and want to keep a complete log of your daily activities.

Pressing down on the Flash surface will activate the device and the LED system can give you some indication of your progress. However, if you don't have your smartphone at hand you'll be second-guessing whether or not you've really met your target.

Overall we found the Misfit Flash to be a pretty accurate tracker, the fact it's also waterproof to 30 metres (98 feet) makes it a little more versatile than the Jawbone UP24.

Verdict: ●●●○○

2 Jawbone UP24

Price: £99.99 / $129.99
Get it from: www.jawbone.com

The simplistic design of the Jawbone UP24 means it wraps snugly around your wrist, and the textured rubber finish gives it a secure fit and feel. Like the Misfit Flash, there's no built-in display, which could be a sticking point for some consumers, especially considering the Fitbit Charge, which does feature a screen, is equally priced.

However, the compatible app gives a great first impression, and it's also straightforward to set up, although we did find it a little slow to sync at times. On a plus note, data is impressively detailed, more so than the competitors', particularly when it comes to activity tracking and sleep analysis. It also offers third-party app support, so it's possible to import data from the likes of MyFitnessPal, RunKeeper etc.

On test we found the built-in vibration motor a useful feature. It buzzes to alert to long periods of inactivity, as well as notifications, although these do have to be viewed on your smartphone, and it will even wake you gently from sleep.

Although the Jawbone UP24 is incredibly accurate, the lack of a screen and the fact it's not waterproof means it's not the most versatile device available on the market.

Verdict: ●●●●○

Modern design
The attractive and well thought-out design means the Jawbone UP24 fits securely around your wrist during a workout.

3 Fitbit Charge

Price: £99.99 / $129.95
Get it from: www.fitbit.com

For its price the Fitbit Charge is a great option, which is why it's our recommended best buy. The modern, attractive design feels weightless on your wrist and the built-in display enables you to check your progress on the go without having to refer to your smartphone.

The easy-to-read OLED display is bright and at the touch of a button you can check the time and date, as well as scroll through to review real-time stats, including steps taken, calories burnt, distance covered and even floors climbed. When synced with your smartphone it will even display caller ID.

To get a more detailed view of the data and set yourself goals, you can use the compatible app or wirelessly sync the device to your computer using the provided dongle. We found the interface is clear and easy to navigate, although data and sleep tracking is not quite as detailed as you'll find with the Jawbone UP24. The device is however compatible with third-party apps, so you can keep an accurate account of your activities.

There is also a built-in vibration motor, which functions as a silent alarm and will also vibrate to let you know when you've reached set goals, as well as notify you of an incoming call. Although not waterproof, for the price, the Fitbit Charge is a great overall performer.

Verdict:

Sleek finish
The small OLED display keeps the Fitbit Charge slim and sleek. It also feels lightweight and comfortable to wear.

4 Garmin Vivosmart

Price: £129.99 / $169.99
Get it from: buy.garmin.com

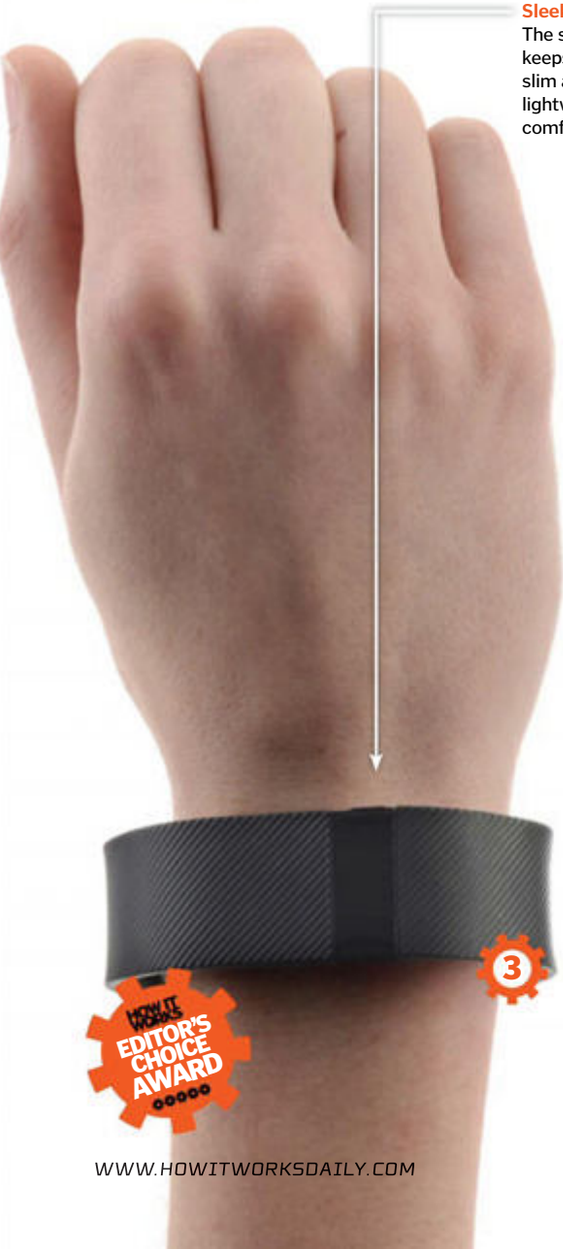
A combination of fitness tracking and smart features gives the Garmin Vivosmart an impressive edge. It's the most expensive device on test, but includes a built-in screen, which enables you to check the time, review notifications, adjust volume and skip song tracks, as well as assess fitness data and adjust some settings without having to continually refer to your smartphone.

The hidden OLED display comes to life with a quick double-tap, although we did find on occasion it could be a little slow to respond. It's also not the brightest, which makes it difficult to see in some conditions.

The compatible app is easy to use, although some options are restricted for iOS users, including the ability to adjust which notifications are pushed to the device. However, fitness data is clearly displayed, although sleep analysis is pretty basic when compared to the Jawbone UP24. Still, the Vivosmart does include a vibration motor for alerts, which can also be programmed to function as a silent alarm.

On a whole we found the Vivosmart lightweight and comfortable to wear. The fact it's also waterproof up to 50 metres (164 feet) is appealing, but it's pretty pricey and there are areas that could be improved.

Verdict:



Hidden extra
The Garmin Vivosmart may not be eye-catching, but gadget lovers will appreciate the hidden OLED display.

BUDGET BREAKERS

The best fitness bands for those willing to stretch the purse strings

Fitbit Surge

The Fitbit Surge is the ultimate fitness performance tracker. It includes GPS tracking, a continuous heart-rate monitor and music control, all for £200 ($250).

Jawbone UP3

The new Jawbone UP3 may not feature a display, but detailed data regarding heart rate, sleep patterns and activities can viewed on the app. It's also waterproof up to ten metres (33 feet) and is priced at £150 ($180).

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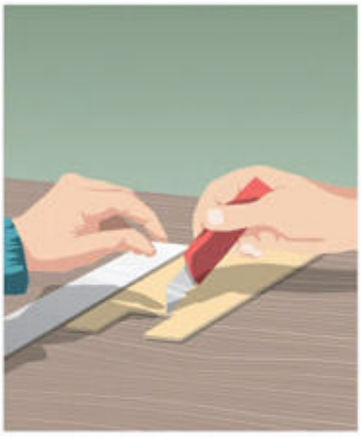
Make a rubber-band car

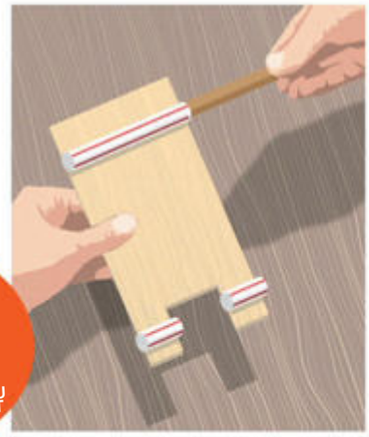
Build and power your very own toy car using simple household items



1 Create the chassis

To create the main body, or chassis, of your car, cut out a 15 x 5-centimetre (6 x 2-inch) piece of rigid cardboard, foam board or balsa wood using a sharp knife or small saw. Then cut a 2.5 x 2.5-centimetre (1 x 1-inch) notch out of one end to create an accessible hole for the rear axle.

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

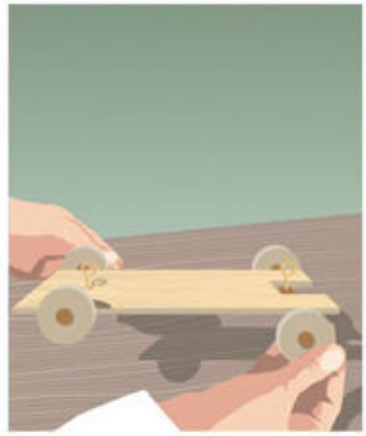


2 Attach the axles

Cut two five-centimetre (two-inch) lengths of drinking straw and glue them across either end of your chassis. Make sure they are both straight to ensure your car will travel in a straight line. Cut away a 2.5-centimetre (one-inch) section from the centre of the rear straw that stretches across the notch. Now thread a 7.5-centimetre (three-inch) long piece of wooden dowel through each straw to create the axles.

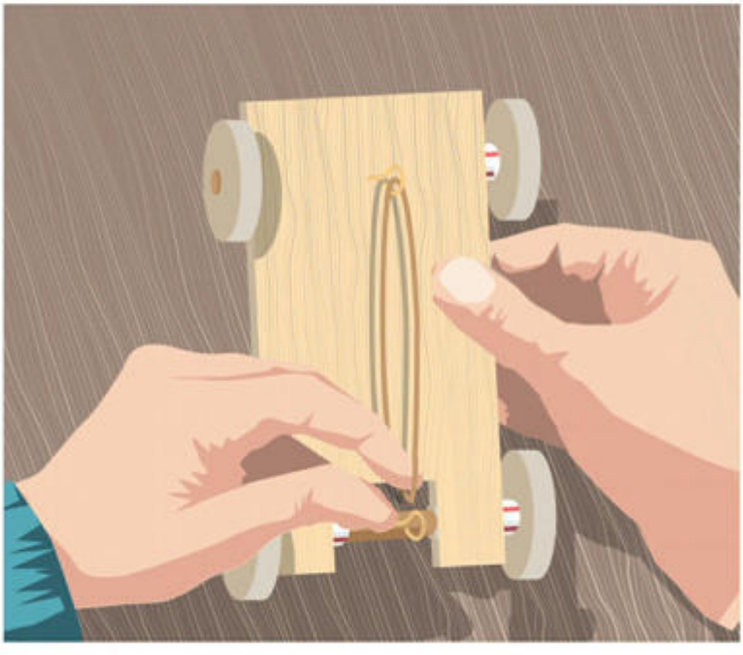
3 Add a catch

Place a small cup hook onto the rear axle, positioning it in the centre of the notch so that the hook is facing the front axle and the screw is facing downward. If you don't have any cup hooks, you can fashion your own catch out of paperclips by simply bending them into a hook shape. If the hook does not fit tight around the axle you will need to secure it with either glue or strong tape.



4 Fix the wheels

Now you can attach the wheels to your car. You could either use plastic bottle caps, cutting a hole out of the centre to thread the axle through, or make your own from circular pieces of rigid cardboard or wood. You could even repurpose the wheels from another toy car. Make sure your wheels fit tight onto the axle and glue them in place if they feel loose.



5 Loop the band

Turn your car over so it is the right way up. Then screw another small cup hook into the chassis just behind the front axle. Make sure the hook is facing the front of the car and loop one end of a rubber band around it. Loop the other end of the rubber band around the screw end of the cup hook on the rear axle, and then your rubber-band car is complete.

In summary...

To power your rubber-band car, simply turn the rear axle several times to wind the rubber band around it. This builds up potential energy that, when you let the car go, is turned into kinetic energy as the rubber band turns the axle.

NEXT ISSUE
- Recycle your own paper
- Make a pinhole camera

Fit an egg into a bottle

Amaze everyone with this clever magic trick that's all about air pressure

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

1 Hard-boil the egg
First you will need to hard-boil an egg by placing it into a saucepan of boiling water for about five minutes. Remove the saucepan from the heat and cover it with a lid, letting it sit for about 25 minutes before removing the egg and dipping it in cold water. Once it has cooled, peel the shell from the egg, revealing the smooth spongy egg white underneath. You could also brush the egg with some vegetable oil to help lubricate it some more.

2 Heat it up
Get a clean, empty glass bottle, making sure the mouth is a little smaller than the narrow end of your egg. Use a lit match to carefully set fire to a couple of thin strips of paper, then drop them into the bottle. This will cause the air inside to heat up and expand as the air particles spread out. As soon as you've dropped the lit paper into the bottle, place the egg, narrow-side down, on top.

3 The egg falls in
As the expanding air tries to escape past the egg, you should see it vibrate. When the fire has consumed all of the oxygen inside the bottle, it will go out and the air will start to cool down. By sealing the mouth, the egg creates a vacuum of this cool air, which takes up less space and exerts less pressure. As the outside air exerts more pressure, it will try to rush back into the bottle, forcing the egg in with it.

In summary...
To get the egg back out of the bottle, you need to increase the air pressure inside. Do this by turning the bottle upside down and blowing into it. By forcing more air in, you raise the pressure, so when you take your mouth away, the egg should pop back out again.

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Letter of the Month

Satellites and space trash

Dear **HIW**,
I love your magazine because of the variety of subjects included in it. I was reading your article on Earth's greatest threats in issue 69 and it got me thinking. With the high amount of satellites in Earth's orbit, could they interfere with each other or other rovers when they are launched or when in use? And if not now, could this become a problem in the future?
Yours sincerely,
Nicholas Woodford

The number of satellites could indeed pose a threat to future launches, Nicholas. There are over 1,000 operational satellites currently orbiting the Earth; their positions must be carefully considered before any prospective launch into space. Of more concern to scientists is the amount of debris currently in orbit. There are believed to be over 21,000 objects over ten centimetres (3.9 inches) orbiting the Earth at a ferocious 29,000 kilometres (18,020 miles) per hour. This is a concerning statistic, and many fear that in the future the chance of a collision-free launch will be very low. With regard to interfering with each other, satellites are carefully designed to reduce the likelihood of this and are always positioned a certain distance from one another. Identifying the source of interference is a tricky process; the investigator needs access to two satellites with overlapping beams in order to geo-locate it.

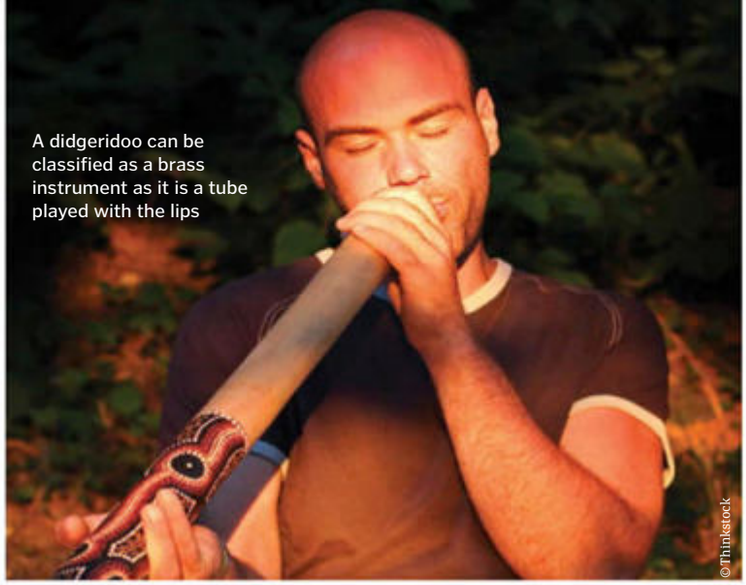
Satellites in geostationary orbit reside at an altitude of nearly 36,000km (22,369mi)

Remembering memories

Dear **HIW**,
Your magazine is the best! I always buy it when I can because there is always something different to learn and new questions I want answering! Something I have always wondered is how does the brain forgets things it wanted to remember? I had another question – but I've forgotten it!
Many thanks
Cavan Guy

Our ability to recall past information can trouble all of us. One plausible explanation for why we forget certain things looks at the different ways in which we access our memories. Studies have shown that if presented with a picture of a person, we are very good at recognising them. However, when we need to voluntarily sift through our memories without a visual reminder, we are much more likely to either misremember or not at all. Make a visual reminder of something you need to remember and you will have far more success.

The brain can gather relevant information to form false memories, allowing you to 'remember' fictional events



A didgeridoo can be classified as a brass instrument as it is a tube played with the lips

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Top brass

Dear **HIW**,
I love reading the magazine each month. However, I have always wanted to know, how do brass instruments make noise?
Thanks,
William Tucker (14)

Brass instruments use our breath to create sound. Blowing into the mouthpiece through pursed lips causes the tube within the instrument to vibrate, generating a musical note. The pitch depends on the tube's size; larger tubes produce lower notes than smaller ones. Although the musician can alter the note by changing their technique, many brass instruments have valves that change the pitch of the notes by altering the tube's length.

"Many fear that in the future the chance of a collision-free launch will be very low"

Pure oxygen

Dear **HIW**,
Could you breathe only oxygen and still survive?
Diego Andaluz (age 10½)

Although we need oxygen to survive, breathing 100 per cent oxygen rather than the 21 per cent found in air can actually damage our bodies. The brain's hypothalamus can be forced into overdrive, flooding the bloodstream with chemicals that can upset the heart's capacity to deliver oxygen to our cells. The pressure the 100 per cent oxygen is delivered at is vital. Astronauts on the Apollo missions received 100 per cent oxygen at a reduced pressure and experienced few side effects. So to answer your question; we could survive if the oxygen is delivered at a reduced pressure.

What's happening on... Twitter?

We love to hear from **How It Works**' dedicated followers. Here we pick a few tweets that caught our eye this month...

Andy Cowle
@HowItWorksmag A must for all #clil #English #teachers My kids love it. *!* love it! #education #magazines #family

Winchester SciCentre
@HowItWorksmag it was lovely to meet you! Looking forward to seeing the article about your visit to the Science Centre.

S Wright
@HowItWorksmag Day trip to Lullingstone Roman villa reached via roads that weren't very straight so not very Roman #greatdayout

Rachel J
@HowItWorksmag Are you going to be out n about anywhere else this year? Daughter still talking about having met you at Bournemouth AirFest!

Debbie Stavert
@HowItWorksmag Love anything with #facts that are fun to learn with the kids

Balanceability
@HowItWorksmag Great article on sense of balance from @HowItWorksmag! #Balanceability

Celery
Just reading through my copy of **@HowItWorksmag** and stumbled across this beauty of a piece! So proud @BAES_Maritime

HOW IT WORKS

Imagine Publishing Ltd
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☎ +44 (0) 1202 586200
Web: www.imagine-publishing.co.uk
www.howitworksdaily.com
www.greatdigitalmags.com

Magazine team

Editor Jodie Tyley
jodie.tyley@imagine-publishing.co.uk
☎ 01202 586274
Art Editor Andy Salter
Editor in Chief Dave Harfield
Research Editor Jackie Snowden
Senior Art Editor Helen Harris
Production Editor Erlingur Einarsson
Senior Staff Writer Jo Stass
Staff Writer Philip Watts
Assistant Designer Jo Smolaga
Photographer James Sheppard
Publishing Director Aaron Asadi
Head of Design Ross Andrews

Contributors
Stephen Ashby, Sarah Bankes, Ben Biggs, Ed Crooks, Ella Carter, Alexandra Cheung, Tom Connell/Art Agency, Sandra Doyle/Art Agency, Alicea Francis, Shanna Freeman, Jack Griffiths, Rebekka Hearl, James Hoare, Ian Jackson/Art Agency, Gemma Lavender, Adrian Mann, Laura Mears, Hannah Parker, Hayley Paterek, Ceri Perkins, Jason Pickers, Lee Sibley, Luis Villazon, Tim Williamson

Cover images
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Advertising
Digital or printed media packs are available on request.
Head of Sales Hang Deretz
☎ 01202 586442
hang.deretz@imagine-publishing.co.uk
Account Manager Jennifer Galvin
jennifer.galvin@imagine-publishing.co.uk
Account Manager Lee Mussell
lee.mussell@imagine-publishing.co.uk

International
How It Works is available for licensing. Contact the International department to discuss partnership opportunities.
Head of International Licensing Cathy Blackman
☎ +44 (0) 1202 586401
licensing@imagine-publishing.co.uk

Subscriptions
subscriptions@imagine-publishing.co.uk
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Circulation
Head of Circulation Darren Pearce
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Production Director Jane Hawkins
☎ 01202 586200

Founder
Group Managing Director Damian Butt

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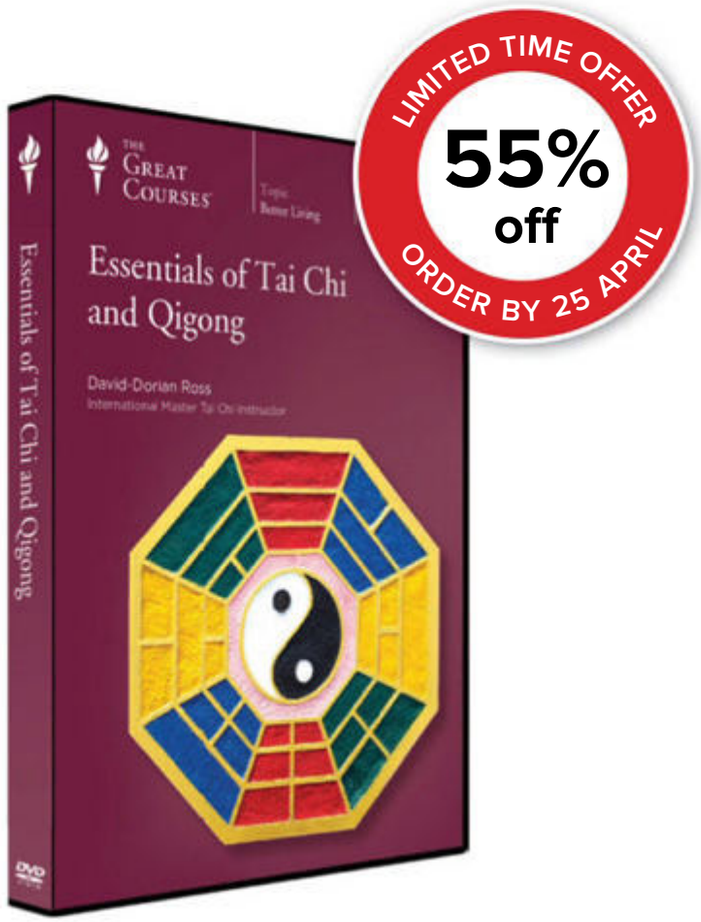

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